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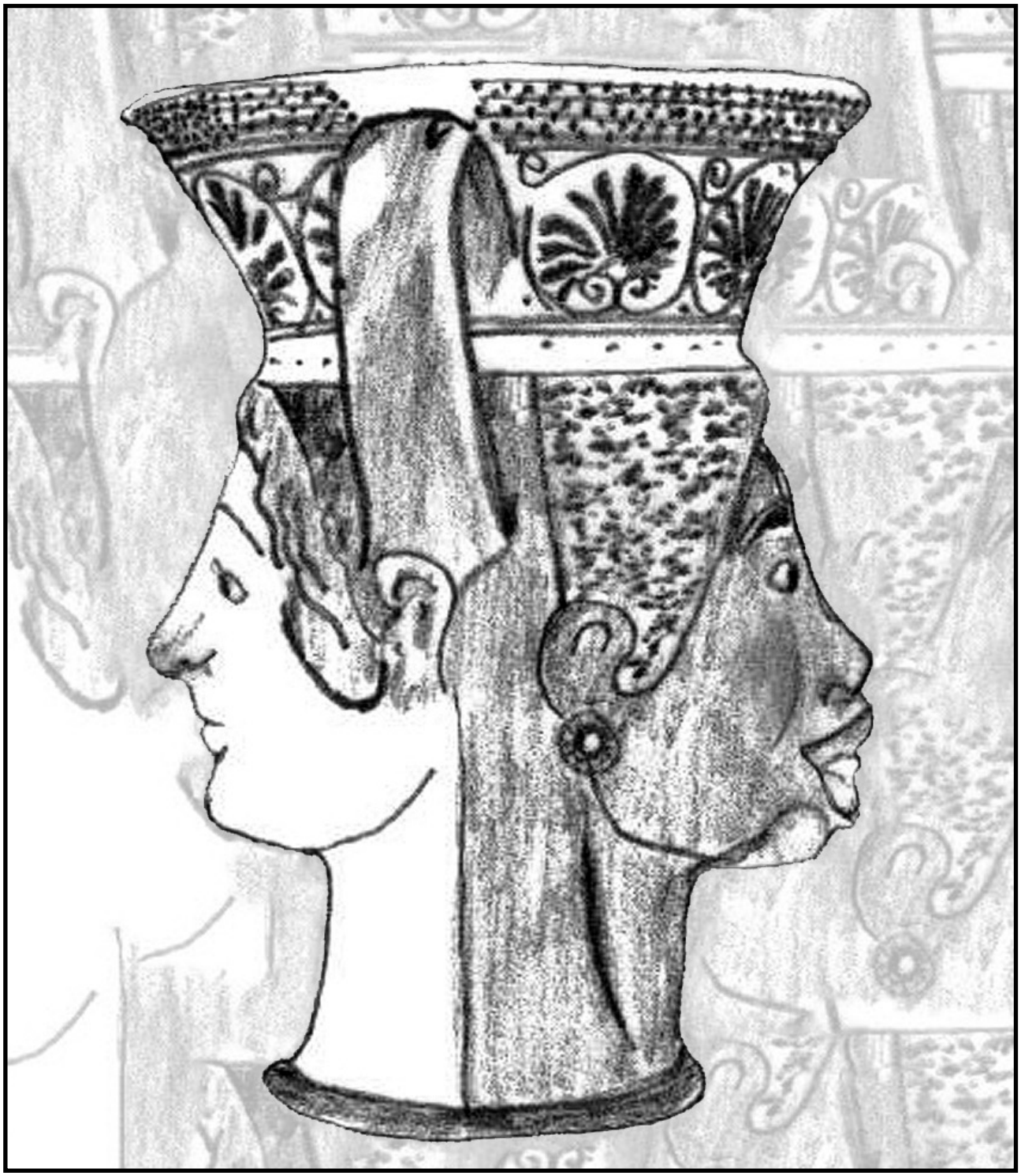

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INQUIRY

The Undergraduate Research Journal of the University of Arkansas

Volume 11 **Fall 2010**

Winners of the 2010 Undergraduate Research Award given by the Teaching Academy

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Cover: Kantharos Attic Bilingual cup; c. 480 BCE. Drawn by Laura Groves, B.A. University of Arkansas, Fayetteville.

FOREWORD

The *Inquiry* journal is a project of the Teaching Academy of the University of Arkansas. The journal is supported financially and conceptually by the offices of the Provost and the Vice Provost for Research. Through print and on-line publication, *Inquiry* provides a forum for sharing the research and creative endeavors of undergraduate students at the U of A.

This issue of *Inquiry* records the scholarly contributions of 16 U of A student/faculty mentor pairs during the 2009/2010 academic year. The first three manuscripts—by Eguchi, Feinstein, and Naglak--are also the recipients of the 2010 Undergraduate Research Award. If readers want some perspective on the breadth and excellence of undergraduate research on this campus, these three articles will provide an excellent showcase. One thing these authors all share, along with the other 13 student researchers published in this issue, is a sense of independence, curiosity, and drive. There are some other patterns in this issue of *Inquiry*, patterns that mirror the world around us. Many of these student authors have drawn their research inspiration from multiple disciplines. For example, Matt Naglak came to classical studies from math, physics, and computer sciences. Alia Biller crafted her research from her broad background in Arabic, linguistics, and psychology. Similar examples can be found throughout.

One new feature this year is the inclusion of two articles in a Research Notes format. These studies were considered by reviewers to be of considerable interest even thought space limitations did not allow publication of expanded versions of the work. Readers will also see that the *Everything is Alive* research project in artificial intelligence on this campus appears to be showcased in this issue. Three very unique manuscripts were submitted by undergraduate students working with this initiative, and publication of all three may whet the appetites of readers to learn more.

As has been true in the past, the number of articles accepted for publication is controlled in part by the size of the journal, and we received many more high quality manuscripts (43 to be exact) than we could publish. The articles included in this issue are drawn from disciplines in five of the undergraduate colleges and schools at the University of Arkansas. The breadth and quality of subject matter included here is testimony to the commitment made throughout the university to research at the undergraduate as well as the graduate level.

Articles are selected for publication after review by faculty members. The Editor and Publication Board of *Inquiry* are grateful for the input of those campus colleagues who have served as reviewers. As Editor, I must also thank the members of the Publication Board who gave so generously of their time, particularly at the end of the spring semester when no one has any free time.

While the papers chosen for publication vary in subject, method, writing style, and manuscript format, they are uniformly excellent in content. As much as possible, we have endeavored to maintain discipline-specific styles to provide students with a publication experience comparable to one they might find in their individual disciplines. I hope you enjoy reading this issue of *Inquiry*.

Barbara B. Shadden, Editor

INQUIRY PUBLICATION BOARD, 2009-2010 ACADEMIC YEAR

The following individuals made the publication of Inquiry possible through their guidance and their willingness to take on reviewing responsibilities at the most hectic time of the academic year.

Ro Di Brezzo, Inza Fort, David E. Gay, Collis Geren, Amy Herzberg, Marcia Imbeau, John Norwood, Molly Rapert, Charles Rosenkranz, Mary Jo Schneider, Murray Smart, Mike Wavering.

SMART OBJECTS IN A VIRTUAL WORLD [1, 2]

By Akihiro Eguchi
Department of Computer Science and Computer Engineering

Faculty Mentor: Craig Thompson
Department of Computer Science and Computer Engineering

Abstract

The coming Internet of Things will usher in a smart semantic world where many more physical objects will be networked so that they can communicate with each other and with humans. This paper identifies protocols that smart objects will need to follow and the ways in which today's virtual worlds can be used to better design and understand these protocols for tomorrow's smart world.

Problem

Pervasive computing is a megatrend. Computing has migrated from mainframes to desktops, from laptops to cell phones. Embedded computing is increasingly integrated into objects such as cars and washing machines. An "Internet of Things," where every individual object has a unique identity provided by technologies such as RFID, is approaching. There is talk of smart worlds full of smart objects. But – what makes a smart object smart?

Objective

The objective of our project [1] is to gain an understanding of how to design "smart objects." Our long-term aim is to help to create a collection of interoperability standards that provides a migration path to convert incrementally a world of ordinary objects into a smart world containing smart objects, one smart object and one protocol at a time.

Related Work

Since 1990, the World Wide Web has been accessed to construct web pages and use URLs to link information. Since 2001, the research community has been actively identifying ways to make the World Wide Web into a "semantic web" [2] so that machines can access knowledge sources and use business rules to locate and reason about web-based information. Smart home and smart car technology [3] methods and standards have been developed to control refrigerators, doors, and other parts of our environment. Radio Frequency Identification (RFID) technology provides a useful, low-cost way to manage identity and communicate with any object. Smart phones are beginning to be used as remote controllers, as a search of Google Patents shows (http://www.google.com/patents?as_q=smart+phone+as+remote+control+device). Recent papers have begun to generalize this work to explore frameworks for smart objects [4][5][6] that identify some of the attributes that make an object smart. Our work differs in that we believe a smart object is more or less smart depending on the standard protocols it supports, and these protocols can change over time. Our work also differs in that we use 3D virtual-world technology to construct and demonstrate the protocols in an understandable manner.

Thesis #1 – A smart object is made smart by the protocols it obeys.

Today's ordinary objects (e.g., a chair, a lamp, a can of corn, or a pet) have interfaces. For example, a lamp has a physical interface consisting of size, shape, flexibility, weight, and composition; a visual appearance interface with aesthetic properties including color, brightness, and texture; a functional interface with an application program interface (API) that humans use to turn the lamp on or off; a power interface for connection to the electric grid; an implicit identity so people can tell two lamps apart even if they look the same; an implicit ownership (*I saw a new car at the dealership. I just bought the car, so now it's mine and used.*); and a compositional interface typically used for repairs. Objects may also have a corresponding repair manual (a model kept at home in a drawer of user manuals), associated images that appear in retail catalogs or in photographs, a location where the owner keeps the spare bulb, and a history and / or schedule of use. This list is not complete.

What additional interfaces would transform an ordinary object into a smart object?

- Explicit identity – Explicit identify could be implemented using RFID tags or other means. Identity provides a way to address each object uniquely. Legal ownership and an object's ontological type are additional interfaces related to aspects of identity.[3] Nearly everyone can afford hundreds of RFID tags (at $.07 each) to explicitly identify all the objects they own, though it is not yet cost effective to do so with inexpensive items such as those purchased at grocery stores. Local identities can be used within an enclave so that only members know the mapping to global identities; thus, the RFID tags in one's home are not meaningful if read from outside.

- APIs supported – A smart object may support one or multiple APIs, and these different APIs may be available for different purposes and to different personnel. The owner may be able to use

[1] Accepted as a position paper at the *X10 Workshop on Extensible Virtual Worlds*, venue: Second Life, March 29-30, 2010, http://vw.ddns.uark.edu/X10. Accepted and presented at *Conference on Applied Research in Information Technology*, sponsored by Acxiom Laboratory for Applied Research, Conway, AR, April 9, 2010.

[2] See YouTube video available on the web at http://vw.ddns.uark.edu/index.php?page=media (see *Healthcare Remote Control and Smart Objects* demo)

the object, but a qualified repair person might be required to repair it.

- Security – Not just anyone should be able to command, control, and communicate with one's possessions. Access control could be used to specify any user's digital rights along with encryption to communicate securely over less-secure channels. Many objects will communicate only with their owners or with a repair person.

- Object-to-object communication – A networked object is one with which humans or other objects can communicate. The network can be wired or wireless, local area or wide area. It may use 802.11* or RFID and may communicate through several messaging languages such as SNMP or WSDL. [4]

- Human-to-object communication – A person needs a way to command, control, and communicate with smart objects. Assuming a person has a way to designate a device and upload information about that device (e.g., its ownership or API), then a GUI or menu-based interface can be used to control or query the device, possibly from a remote location. [5]

- Micropayments – There may be a cost for accessing, communicating with, or using an object which one does not own. Some objects may have longer life spans and better sustainability properties than others.

- Plugins – A basic device might be extendible with plugin behaviors. The functions of a simple thermostat can be extended with a scheduler plugin to designate times of the day and days of the week and / or with a history-logging plugin to remember all past settings, which is useful for calculating energy usage.

- Driver Update – As with other kinds of software, a device driver update service is needed.

The above protocol list is incomplete, and additional useful protocols are mentioned below. Each item needs refinement, and one could argue about any or many of the characterizations. For instance, implicit identity is sufficient for many purposes, such as "Buy me one of those lamps."

Does an object have to support all interfaces to be smart? Is there a core set? Not necessarily. A degenerate smart object might contain no additional interfaces as long as it is possible to add interfaces from the list. The binding time for adding smart object protocols could be during the design or assembly, or it could be dynamic. For example, protocols could be added as needed during use. As interfaces are added (or removed), the object becomes increasingly (or decreasingly) smart.

Are all the smarts located inside the object? No, but some might be. The following is a simple algorithm for making a smart world. Add an item-level RFID to many or all objects, which can be done inexpensively for all objects in the home. Add an RFID reader to a smart phone, just as GPS was recently added to cell phones and RF plugins are now being added to control televisions and stereos. Since the smart RFID-enabled phone can now read the tags of any object and since the phone is already connected to the Internet, all information about the object can be downloaded from the web cloud. Chairs with RFID tags will immediately become smart. Of course, to achieve full value, future devices will need to be manufactured with network controls so that people can remotely control their behaviors. This is not to say that smart objects will contain no processing. Rather, the knowledge and processing that makes a smart object smart might be contained within the object, the controller, the user, and/or various information sources on the Internet, and different smart objects may distribute this information differently. For instance, the Internet might be only intermittently available, and smart objects might need to cache some of the log history to upload later.

A significant challenge to the widespread adoption of smart objects involves reducing complexity while increasing functionality. Today, managing 5 to 10 network objects is challenging and requires humans to run virus scans, set up firewalls, change permissions, run defragmenters, and download security updates. Many users (e.g., the elderly) are challenged by this complexity and just want unintelligent, simple, reliable, and low-maintenance objects. Smart complex objects will compete against unintelligent objects on criteria such as cost, reliability, functionality, and ease of use. In a world where every user controls hundreds to millions of smart objects, having hundreds or millions of separate remote controls (one per object) does not scale, so truly universal remotes (e.g., smarter smart phones) will be needed. These Star Trek-type communicators are called soft controllers [7] because they import different object interfaces from the objects and network. Furthermore, different users may see the object differently, so one user may have a simple controller while another has a more sophisticated controller. With a more sophisticated controller, for example, the typical problem of hitting the input button on a TV remote and not understanding how to reset it is solved.

Thesis #2 – Virtual Worlds are good places to develop Smart Object Protocols.

In the future, when people go to the store, buy a smart object, and bring it home, a 3D model of the object will be installed into the virtual model of their smart home (another protocol). Changes people make in the real world may affect the model and vice versa, resulting in a bidirectional mirror world [8].

In the meantime, before the real world converts to smart-object protocols, it is necessary to understand how such a world will function. What will it be like to manage and maintain thousands of smart objects, especially when many people have trouble maintaining tens of complex semi-literate objects such as laptops, stereos, and televisions despite having a drawer full of user manuals? Certainly, people do not want to have to remember to set manual permissions on the TV channel by channel when a house-guest visits, but each family member might want an individual

[3] Just because an object has identity does not mean that everyone has access to all aspects of identity. For example, we do not tell each other our names or Social Security numbers except when there is a reason.

[4] An additional interface for this list of protocols is Business Rules and Policy Management. For example, medical personnel will need a way to control collections of objects so that a smart IV drip can synchronize with a smart blood pressure machine, as discussed later.

[5] People do not want simply to talk to one individual object at a time. Sometimes, they want to talk to collections of objects (e.g., "Turn off the lights and the heater in the bedroom when I leave for work.").

list of favorite channels. The world needs to become simpler, not more complex. Therefore, uniform and simple ways to manage a smart world are needed. Virtual worlds provide a way to manage and manipulate smart objects, and simulating the objects in a virtual world helps people imagine how new devices can change the world. In addition, since development and testing in a virtual world may eventually be less expensive than it is in the real world, this approach to prototyping and testing could provide advantages over real-world prototyping and testing. In all likelihood, smart-object interface protocols will be platform-agnostic, operating in either the real or the virtual world.

Thesis #3 – Standards will be needed soon.

Based on our description of smart objects, some objects are already smart, and more are becoming smarter every day. A migration path is in place that is already causing more object types to be made smarter, application by application. For example, smart home entertainment, security systems, and washing machines are typically not interoperable. To get the most value, interoperability standards will be needed to enable plug-and-play so that all objects obey a suite of smart-object protocols, possibly with many implementations. Understanding more about such a suite and early testing of the suite can accelerate progress toward a universally smart world. As noted above, virtual worlds provide a way to design and test these protocols.

Prototype

To experiment with some smart object protocols, we developed a collection of smart healthcare objects in the virtual world Second Life. We toured the University of Arkansas School of Nursing's training facilities with the original intent of determining how to overlay training scenarios on virtual world architectures (still an interest), but our research focus became how to build smart objects for training. Screenshots are provided to give the idea of what we developed, and videos demonstrating the functions of these objects are available on the web [Smart Objects and Remote Control in a Healthcare Setting (http://www.youtube.com/watch?v=YlsE3AVnO4Q); Using Second Life for Healthcare Training (http://www.youtube.com/watch?v=MqaeE1bp2Qo)].

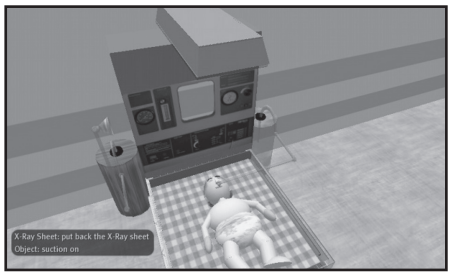
Smart Objects

As can be seen, our selected smart objects were:

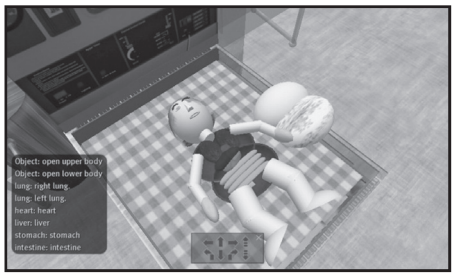
- A hospital bed with several functions for the patient's comfort, including a bed angle adjustment function, a fan switch, and a pullout table.
- A wall-mounted air conditioner / heater that can be turned on or off or adjusted from cool to warm, as visually displayed with blue and red particle effects.
- A human-scale dummy for nurses' training. We developed an infant dummy that can be opened to show the internal organs. The name of each organ is displayed when activated.
- An infant warmer with mechanical arms to give the infant oxygen and to measure suction. The machine can display an X-ray from a nearby portable X-ray machine, and it also has a drawer and a pullout table.
- A portable X-ray machine with a screen on

HILL-ROM Stabilet Infant Warmer

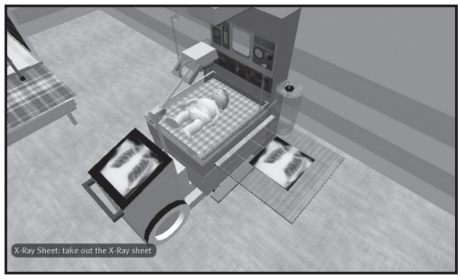
Infant dummy in infant warmer



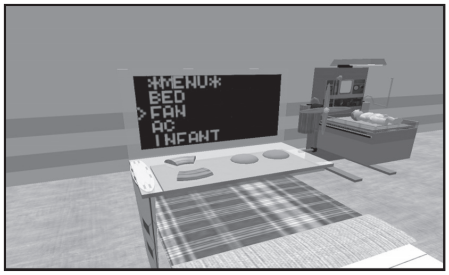
Baby warmer machine with multiple functions



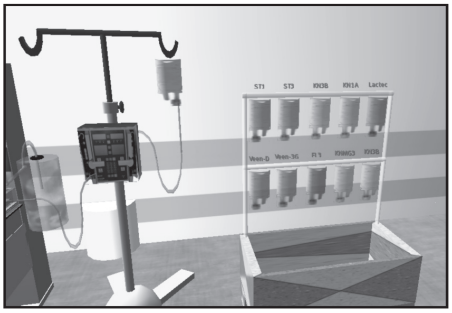
Dummy with several training functions for nurses



Portable X-ray machine



In-world soft controller prototype to control smart devices



IV drip machiine with a bottle changing function

which a digital picture of the X-ray is displayed. When the machine is clicked, it moves its arm upward and approaches the object. Then, the red particle is shown as the X-ray picture is printed on the X-ray sheet in the infant warmer and is displayed on the digital screen. When the machine is clicked again, it returns to its original place and turns off the digital screen.

- An IV drip stand. See the training discussion below.
- A search robot that roams around the virtual healthcare clinic to search for and catalog other smart objects. The robot has a remote control and can leave the user's sight to discover new smart objects as it traverses the clinic independently. A handheld GPS control device with scheduling capabilities can store the current location of the user as he or she enters the checkpoints that the robot will follow. The user can create fixed paths which the robot will traverse by itself. An RFID tag, an identification tag which responds to an RFID light source, responds by giving its identification information. The robot's position can be approximated based on its response to the RFID light emitter.

Soft controller

In addition to the scripted smart objects described above, we developed a protocol for all of our smart objects so that they can be controlled in a uniform manner. All of our smart objects in Second Life use listen event handlers (using Linden Scripting Language) executed when the llListen function receives a chat message that satisfies a condition in an assigned channel. As a result, all devices accept commands from external sources, either avatars or other smart objects.

A controlling device shows the menu of functions for each smart object on the soft controller screen. Avatar users can choose from the menu and control the devices. Since we use the same format of input for each smart object, there can be more than one controller. The controller has text-based instructions on its screen using imported Roman letters.[6] The names of smart objects in the range are displayed on the screen, and the user is asked to choose one. Then the functions of the chosen device are displayed on the screen, and the avatar can choose from the list and send the command to the device.

Instead of a real-world frequency band such as infrared, in Second Life, various channels are used to communicate between devices and avatars or among devices. All smart objects are in one sense connected to each other because all the devices can be controlled by one controller. Although each device has different uses and different commands and works independently, a common input format will result in a universally formatted API.

Training

We developed two training scenarios:

- The infant dummy has a function that trains nurses in monitoring the saturation of peripheral oxygen (SpO2) or the blood-oxygen supply. When a trainer avatar types "/5 start SpO2," the infant starts with 100% SpO2, but the level decreases. The infant dummy's face becomes paler as it loses SpO2, and if the SpO2 drops below 75%, the infant dummy dies. When the SpO2 drops below 95%, a monitor shows the message "problem zone." When the level goes below 85%, the message "danger zone" is displayed. When the nurse avatar administers oxygen, the infant dummy gradually stabilizes as the SpO2 returns to 100%.
- Different IV medicine bottles are used for another nurse training simulation that allows nurses to gain virtual practice in setting the proper infusion bottles. Training is begun by touching the console on the IV drip stand. A prompt instructs the nurse to set a certain bottle. If the procedure is completed successfully, a new bottle is prompted. This process continues until training is complete, after which an overall score is produced.

Actual nursing dummies are expensive and are available only at nursing schools and similar facilities. We originally conjectured that using virtual worlds to simulate nursing dummies and associated procedures could accelerate training for nurses anywhere in the world at any time and at no cost. We still believe our conjecture is valid but to a more limited extent. The virtual world can familiarize nurses-in-training with devices, their operation, and procedures and thus can be used for training. However, certain actions such as learning the physical action of administering a shot or the fine motor skills needed to open a latch still require hands-on experience.

Potential Impact

An interesting exercise is to consider an object and ask, *If this object could talk, what would I want to ask or tell it?* The object might know about its manufacture history, its similarities to and differences from other types of devices, its maintenance requirements and history, its location and environment, and other information. Simulating devices in a virtual world can provide a new means of understanding how devices operate and how they are repaired, leading to a potentially more interactive approach to the traditional training manual or training video. Usually, to create a real-world test model requires significant funds; however, a

virtual-world simulation is often much less expensive and can be made available anywhere in the world for little or no cost. Although there will be some differences between a virtual object and a real-world object, simulations have a useful purpose.

A problem with many Second Life scripted projects is that avatars other than the developer do not know whether the object is scripted or how to operate it. Even if a device has many functions, it is useless if the user cannot learn how to control it. Therefore, not only the communication between devices but also the communication between the device and the user is important.

Establishing a standard interoperability infrastructure for smart objects makes it possible to mass produce interoperable smart objects, real and virtual, that are available to users anywhere in the world, thus accelerating the move toward a smart world. Creating a unified, extensible standard protocol for controlling smart objects solves this problem and makes it possible to control all such devices from a controller device. The controller can upload the controls from any device, even devices it has never encountered before. Separating the interface of a device from the implementation benefits end users and developers for the same reason that pull-down menus benefitted end users in the 1980s by giving a common look and feel to a wide variety of applications. Developers benefit because separating the interface from the device can reduce the cost of designing physical interfaces where there are no standards. The end user benefits because a uniform thermostat controller can be used with any thermostat without the user's needing to learn the custom interface of each new thermostat. In other words, it is easier to control unfamiliar devices because the interface style is familiar.

With a uniform interface for smart objects, it is easier to build higher-level interaction protocols for controlling assemblies of objects. Many of the business rules (another protocol) for such assemblies are application-specific, but the ability to see physical objects as exporting their interfaces in an object-oriented programming style bodes well for providing higher-level mechanisms for composing them together.

Just as the World Wide Web uses URLs to link information, a virtual-world URL that includes a region and an x/y/z location can be used to teleport to a location in a virtual world. Similarly, RFID tags and smart phones can be used to locate objects in the real world. Real and virtual objects have unique identities. We can associate additional information with these identities in web- or cloud-based data sources and associate information and rules with these objects. In this way, we can view our work as extending the "semantic web" directly toward a "semantic world" where more information about any physical object and the ability to control the object (subject to access control permissions) may be available to humans via their soft controller smart phones.

Future Work

Areas for future work include the following:

- Determining and removing limitations of Second Life as a simulation platform. [9]
- Determining standards for representing 3D objects – SL prims do not mesh well with CityGML/Collada and AutoCAD standards. Some applications may benefit from more or less modeling accuracy. Should we compose a proverbial elephant with a modeling notion of a top prim?
- Improving identity management so that an object retains its identity even if it is stored and retrieved.
- Improving access control so that it is easier to manage shared objects. In Second Life, many students build interesting objects and then graduate from the program without removing all protections; as a result, others in the group cannot build on the work.
- Determining how to represent interfaces in a general manner, e.g., using SNMP, WSDL, or other standard approaches.
- Gaining experience in combining the smart-object protocols and implementing them in a variety of ways, including using smart phones as platforms.
- Extending smart phones with RFID readers and smart objects with network actuators.
- Arranging the hundreds of thousands of real-world smart objects into 'lower ontologies" to make it easier to develop protocols using categories and inheritance. [10]
- Identifying additional smart-object protocols, e.g., touch, taste, and smell.

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Mentor Comments

Professor Craig Thompson provides insight into the virtual world research domains and their potential value to us in the future. Akihiro's paper was the recipient of an Undergraduate Research Award, but two other papers in this journal issue – by Kumar and by Starling – also take on the challenge of current and future applications of artificial intelligence.

For the past three years, my research has involved how to use 3D virtual worlds like Second Life to explore what the real world will be like when every physical object is a network object, with its own identity, behaviors, and the ability to communicate with humans and other objects. While this may seem far-fetched, it is happening rapidly as cheap RFID tags reach consumers with smart phones that can connect to Internet information repositories. Very soon, people will use smart phones as remote controls for not just TVs and stereos but many other interactive objects. They will be able to point at a real-world object to get more information similar to the way we follow web links today. In Fall 2009, I taught Artificial Intelligence where term projects focused on how to build such a smart world. All of my students were seniors or graduate students – except one sophomore, Akihiro Eguchi. For his term project, Akihiro decided to model healthcare equipment, in particular nurse mannequins and associated medical equipment to demonstrate the idea of how to model smart objects using virtual world technology. Akihiro visited Dr. Nan Smith-Blair, associate professor and interim director of the University of Arkansas' Eleanor Mann School of Nursing. She provided a tour of their nursing facilities and demonstrated nursing mannequins and associated equipment. Akihiro took pictures and notes. All was quiet for about a month, and then it came time for project demos. Akihiro's was absolutely excellent. Not only did he model the mannequin and equipment, he also demonstrated a full scenario of how to use a model of a smart remote control device to query a smart object for its programming interface. The interface is copied from a virtual object to the virtual remote device. Then the remote can be used by a human to control the object. Akihiro even built a robot that wanders through our virtual hospital to discover smart objects that humans can then communicate with. Akihiro's work clearly demonstrated several important aspects of how virtual worlds can model future ubiquitous computing. See Healthcare Remote Control and Smart Objects YouTube video – available on the web at http://vw.ddns.uark.edu/index.php?page=media (). In Spring 2010, Akihro, still a sophomore, took my graduate course Modeling Healthcare Logistics in a Virtual World. He continued to refine his work adding training scenarios and also retail supply chain scenarios. He wrote a paper based on his work "Smart Objects in a Virtual World" for the X10 Workshop on Extensible Virtual Worlds (http://vw.ddns.uark.edu/X10, March 29-30, 2010). This international workshop, organized by myself and members of the IBM Academy of Technology, attracted world leading developers and academics in the emerging virtual world field. The 2-day event was held entirely in Second Life. Akihiro attended the event and, as a scribe for several sessions, took careful notes. This summer, Akihiro is taking advantage of an UA Honors College travel grant to present our paper "Towards a Semantic World: Smart Objects in a Virtual World" in the Web Virtual Reality and Three-Dimensional Worlds Workshop (IADIS WEB3DW2010) in Freiburg, Germany, 26-31 July 2010. Also, during the summer 2010, Akihiro applied for a UA Undergraduate Research Grant and is working with CSCE PhD candidate Josh Eno to help analyze data from Josh's virtual world search engine to see if we can rapidly classify virtual world objects into an ontology classification and can query to find, say, all Second Life parcels that are focused on healthcare, supply chains, RFID, or other affinity groupings. Akihiro's work and our team's crosses over from virtual worlds to real world pervasive computing and is in the vanguard of technologies to build a smarter world.

GEOLOGIC MAP OF THE NEZ PERCE DRAINAGE BASIN, SOUTHWESTERN MONTANA

By Rose Aimée Feinstein
Department of Geosciences

Faculty Mentor: Margaret Guccione
Department of Geosciences

Abstract

A geologic map of the Nez Perce drainage basin in southwestern Montana offers an understanding of the developing paleotopography of the area following the Laramide orogeny, ca. 65 ma. In this project, a small drainage basin was studied in detail, focusing on the geomorphology, structure, lithology, and ages of the various rock units. Based on the results of these studies and the relationships found among four major gravel units mapped within the basin, the basin development was approximated. The youngest unit is a fine-grained (mean diameter = 8.23 cm) channel deposit within Nez Perce Creek, sourced from within the basin, based upon gneiss and quartzite derived from the present drainage. The next-youngest unit is a fine-grained (mean diameter = 10.92 cm) alluvial sheet deposit forming broad flat surfaces adjacent to Nez Perce Creek in the central basin, which was also sourced from within the present drainage based upon gneiss and quartzite derived from the present drainage. The next unit, a coarse-grained (mean diameter = 22.90 cm) Miocene gravel creating the western divide of the basin, was sourced from the Highland Mountains to the north. The oldest unit, a coarse-grained (mean diameter = 39.88 cm) debris flow, is interlayered with Eocene basalt and rhyolite tuff, allowing its age to be bracketed to ca. 48 ma using Ar39/Ar40. Based on unique lithology, this unit was sourced from the Pioneer Mountains to the east. One large fault separates Archean gneiss bedrock on the east side of the basin from younger gravel deposits on the west. Several younger normal faults within the divide gravel indicate tectonic activity more recent than the Miocene time. This evidence of recent faulting, along with a lack of evidence of geomorphology shaped by fluvial erosion, indicates that basin development was more recent than previously assumed (Reynolds, 1979; Rupple, 1993) and was controlled more by structural than by fluvial forces.

Introducion

The Basin and Range region covers much of the western United States and southwestern Canada. It is characterized by alternating north-south trending mountain ranges separated by broad basins, locally called "holes" (Fig. 1). The northern portion of the Basin and Range includes an area in southwestern Montana that extends from a strike-slip structural discontinuity, the Lewis and Clark line, at the northern margin to the Snake River Plain and the Yellowstone Plateau at the southern margin (Reynolds, 1979; Wernicke et al., 1987). In southwestern Montana, the geology and geomorphology of these isolated mountain ranges result from several periods of tectonic activity which changed from compressive forces with resulting folding and thrust faulting that dominated during the Laramide orogeny (mountain building event) beginning in the late Cretaceous (ca. 65 ma) to dominantly extensional forces during the formation of the Basin and Range, beginning ca. 55-49 ma (Paleocene to middle Eocene). Extension continued across a wider belt than the initial deformation area after ca. 45 ma (middle Miocene) to the present time (Constenius, 1996).

Three major hypotheses have addressed details of the Basin and Range development within southwestern Montana following the initial compression and thrust faulting of the Laramide orogeny. The first hypothesis suggests that the basins and mountain ranges present in southwestern Montana today are products of normal dip-slip faulting resulting from crustal arching and crustal extension beginning in the Cenozoic (e.g., Scholten, 1968; Reynolds, 1979). The mountain blocks attained their general present-day outlines in the middle Miocene (15 ma), and uplift has continued to the present time. Fault scarps on the east sides of the basins are steeper than those along the western basin margins, and the basins are filled with 100-3000 m of Cenozoic sedimentary and volcanic detritus (Reynolds, 1979). The first hypothesis considers each mountain range as an isolated faulted block, not a structural whole (Rupple, 1993).

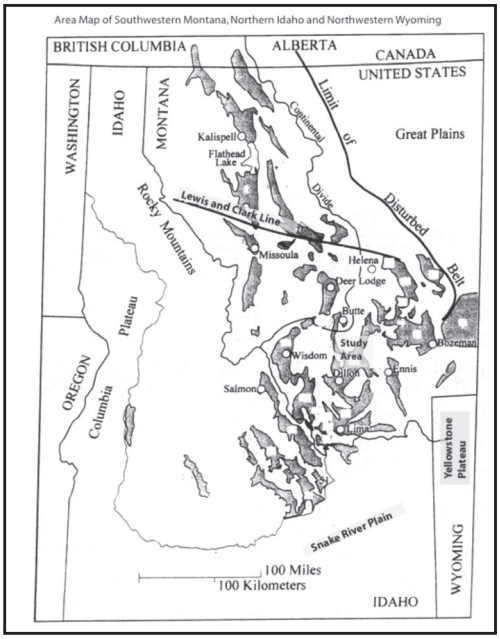

Figure. 1 Map of study area and surrounding features modified from Rasmussen (2003).

As a second hypothesis, Rupple (1993) suggested that extensional collapse began in the middle Eocene (40 ma) and that the deep basins and rhombohedral-shaped ranges present today had formed by the late early Miocene, ca. 15 ma, along pre-

existing north-northeast and northwest oriented faults. In contrast to previous workers, Rupple argued that more recent (Pliocene) fault movement has been primarily along the north-northeast faults that have primarily experienced strike-slip (lateral) or oblique-slip (lateral and vertical) movement rather than dip-slip movement. Causes of reactivation along the existing northwest-trending faults include both extensional collapse due to doming and lateral extrusion due to the volcanism that produced the Yellowstone Hot Spot (Rupple, 1993).

Presenting a third hypothesis of Cenozoic basin development in southwestern Montana, Fritz and Sears (1993) proposed that the modern basins and mountains formed only in the last 2 million years. After the Laramide orogeny and by the early Miocene (20 ma), extension formed broad basins which filled with igneous flows and volcaniclastic sediments. As stated in the previous hypotheses, this Fritz and Sears state that a broad valley that drained southeast existed between 16 and 6 ma and partially filled with more sediment. This broad valley was broken up by the activity of the Yellowstone Hot Spot so that some sections of the paleovalley were uplifted to form mountains and other sections were dropped to form the smaller present-day basins. Locally, this deformation caused flow reversal of some rivers and a northeastern shift in regional drainage. In contrast to Reynolds (1979), Wernicke et al. (1987), and Rupple (1993), Fritz and Sears argued that the modern mountains and basins of southwest Montana were ≤ 2 ma old. Unlike Rupple (1993), Fritz and Sears also argued that movement along the Quaternary (< 2 ma) faults was more vertical than strike-slip and was responsible for the fragmentation of the Miocene and Pliocene (Neogene) drainage network.

All three hypotheses recognize that thick sediment accumulated in the basins of southwestern Montana during the Paleogene and Neogene (65 – 2 ma), though they offer different details of fill history. This fill, the Bozeman Group, has two formations and is widespread throughout southwestern Montana (Kuenzi and Fields, 1971). The older Renova Formation contains fine-grained volcanic sediment that reflects deposition in low-energy flood plains and ponds of a 200 km-wide basin beginning in the middle Eocene (Paleogene), ca. 42 ma, and continuing into the early Miocene (Neogene), ca. 16 ma (Fritz and Sears, 1993). An angular unconformity representing 1-3 million years separates the Renova Formation from the younger Sixmile Creek Formation. The Sixmile Creek Formation was deposited during the late Miocene and Pliocene, ca. 5 - 16 ma, and includes abundant coarse-grained gravel, reflecting deposition in fast-moving streams (Kuenzi and Fields, 1971). Quaternary sediment and basalt flows unconformably overlie the Sixmile Creek Formation, and the former reflects increasingly localized patterns of deposition as the streams incise the basin fill of the half-grabens. Today, Quaternary sediment forms terraces, and floodplain streams incise and rework older basin deposits (Kuenzi and Fields, 1971).

The multi-staged structural and depositional Cenozoic history of southwestern Montana hypothesized by most researchers (e.g., Rupple, 1993; Fritz and Sears, 1993; Rasmussen, 2003) implies that each modern drainage basin is broadly similar but has locally unique tectonic and depositional histories. The sediment sources of the gravel fill may be from outside the present drainage basin, and flow paths may have changed directions. The large basin(s) that developed during the Eocene was (were) probably later broken into smaller basins with more localized drainage as tectonic uplift continued, either during the Miocene (Neogene) (Rupple, 1993) or the Quaternary (Fritz and Sears, 1993). These structural basins have controlled the modern drainage, and streams now rework sediment from within the drainage basin.

The Nez Perce Basin lies between two major faults and thus forms a small drainage that is part of the larger Jefferson Valley (Fig. 2). Within the basin, several rock types, including gravel, intrusive and extrusive igneous outcrops, and metamorphic bedrock, were noted. The purposes of this project are to identify, characterize, date, and map all Cenozoic and Quaternary gravel units within the basin so that the lithology (rock type), texture, age, and topographic position of each unit can be used to identify the paleotopographic evolution of the area; interpret the tectonic events that have affected the formation of the small Nez Perce basin; and evaluate the formation of the adjacent large Jefferson and Divide basins.

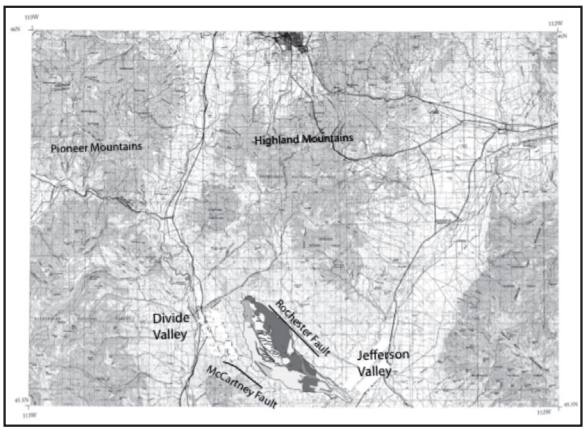

Figure. 2 Regional map of study area and surrounding features.

Methods

Map. Field mapping was done on a 1:24,000 scale, using the 1961 Twin Bridges SW, Wisdom, and Nez Perce 7 ½ minute topographic maps as base maps. All contacts were drawn on the paper maps in the field. A hand-held Garmin global positioning system (GPS) device was used to locate sample locations of the various gravel units and of the igneous rocks for Ar40/Ar39dating. North American Datum 1927 was used on the GPS to coincide with the projection system used on the topographic maps.

In the field, various methods were used to identify, distinguish, and map the metamorphic, volcanic, and gravel units. Metamorphic units were identified using the rock type, such as gneiss or amphibolite, and the dominant mineral, such as garnet. For example, the Archean garnet gneiss was named for its abundance of large garnets. The strike and dip of the foliation were measured at various outcrops in the map area wherever a change in orientation was noted.

Volcanic units were identified on a textural and mineralogical basis. Extrusive volcanic rocks were distinguished from shallow

intrusive volcanic rocks by their relatively small crystal size, the presence of air bubbles or vesicles, and the relationship with the adjacent units.

Gravel units were distinguished by their relative grain size and angularity, lithology, and topographic position. The presence of some key lithologic fragments, such as pink quartzite and quartzose sandstone (Proterozoic Belt Group), gneiss and schist (Archean metamorphic rocks), and brown sandstone (Pennsylvanian Quadrant Formation) were noted. Topographic position such as the presence of gravel on the divide or a position within a valley and adjacent to a channel was also used to distinguish the units.

The thickness of each sedimentary deposit was determined using the elevation of the upper and lower contacts on the topographic map. Where a unit was restricted to a small area, the minimum thickness was determined using a Brunton compass to repeatedly measure the eye height of the mappers perpendicular to the bedding through the exposure.

Each unit recognized within the map area was given an informal map name and tentatively correlated with a regional stratigraphic unit. Units included Archean metamorphic gniess, schist, amphibolite, marble, and diabase; Paleogene (Eocene) basaltic and rhyolitic shallow intrusive and extrusive igneous rocks; and Neogene (Miocene) and Quaternary (Pleistocene and Holocene) diamictic and gravel units. All units in the study area are included on the map, but a comprehensive discussion of only the Cenozoic units, including the Paleogene (Eocene) igneous rocks and the Paleogene, Neogene, and Quaternary sand and gravels, is provided in this article.

Digital raster graphs (DRG) of the three maps were used with ArcGIS software to create the digital geologic map. The boundary of the map area, the basin of Nez Perce Creek, was drawn onto the maps in ArcMAP. Standard geologic map symbols and colors were used (Remane, 2002).

Gravel Lithology and Texture. The lithology and texture of the gravels were identified and quantified at 19 locations and included 1 to 10 sites within each tentative map unit. Most (15) of the sample locations were on flat surfaces to reduce the effect of erosion; however, these sites were the most intensely weathered locations, so only the most resistant lithologies were preserved. Four of the 19 sample locations were chosen on either the north- or south-facing slopes of the divide gravel unit in order to evaluate slope processes on the unit. At each location, a 1 m2 area was marked on the ground. The number of cobbles greater than 12.5 cm in diameter at the ground surface was determined as a qualitative measure of the grain size of the deposit and the presence of loess and / or degree of surface erosion. Twenty-five cobbles were removed from the upper few centimeters of the 1 m2 area, and the maximum diameter of the five largest cobbles was measured. Roundness was qualitatively noted in the field.

All 25 cobbles were broken and the lithology recorded. Most lithologies found in the basin were easy to identify, but weathered sandstone, quartzite, and chert cobbles had some similarities and were distinguished based on the following criteria. Sandstones were subdivided based on color: brown, white, or red. Metamorphic quartzite was distinguished from quartz-rich sandstone by a greater degree of cementation, larger apparent grain size, and increased hardness due to recrystallization. Quartzites were subdivided into red, purple, pink, and grey varieties. Chert was identified by the absence of a granular texture.

Ar40/Ar39Dating. Samples of unweathered or very slightly weathered igneous rocks, including basalt, rhyolite, and rhyolitic tuff, were collected for Ar40/Ar39 dating. For basaltic and rhyolitic flows and dikes, multiple samples were collected from each location, and individual samples were labeled. Thin sections of all rock types to be dated were examined to identify the mineralogy and evidence of weathering. Based on examination of thin sections, the eight best samples (least weathered samples and those that included sanidine, biotite, and/or amphibole) were selected for analysis. In some cases, multiple samples from a single location and/or multiple grains from a single sample were analyzed. Four of the selected basalt samples were analyzed using a whole-rock technique. Individual mineral grains (sanidine and biotite) from four additional samples of rhyolitic tuff, granodiorite, and rhyolite were also analyzed.

For the whole-rock analysis, each selected basalt sample was crushed using a jaw crusher and a disc mill and then was hand sieved. The fraction between # 80-100 (180 – 150 microns) was retained, washed, and oven dried. A hand magnet was used to remove large magnetic grains from the dried sample, and the remaining sample was put through a magnetic separator to remove additional small magnetic phenocrysts and inclusions. When the sample looked clean under a low-power microscope, it was rinsed with a 10% hydrochloric acid solution for 10 minutes in an ultrasonic bath, rinsed with deionized water, and oven dried.

For the rhyolite and rhyolitic tuff, single minerals were dated. The rocks were crushed using a jaw crusher and disc mill. These crushed particles were dry sieved to separate the crushed particles into > 500 micron, 250-500 micron, 180-250 micron, and 125-150 micron fractions. Each fraction was examined under a low-power microscope, and the presence of whole and clean biotite, sanidine, and amphibole grains was noted. The fraction with the cleanest grains was washed and oven dried. The biotite, sanidine, and amphibole grains were separated by putting the sample through the magnetic separator to remove most of the magnetic material.

Subsequently, the remaining nonmagnetic particles were put into a heavy liquid to separate the desired minerals. The heavy liquid used to separate biotite had a specific gravity of 3.17 or 2.85 based on the fraction size chosen and was obtained by mixing Bromoform and Methylene Iodide. For sanidine, the heavy liquid mixture had a specific gravity of 2.6. After the desired grains were removed from the sample, they were rinsed with acetone and oven dried. For biotite grains, the sample was shaken over a clean piece of white paper, and the cleanest grains were removed with tweezers. The handpicked biotite grains were put in an ultrasonic bath for 5 minutes to remove dust. The sanidine grains were examined under a low-power microscope, and tweezers were used to pick approximately 100 grains for analysis.

Two machines were used to date the minerals. The individual sanidine grains were run in a MAP 216 mass spectrometer and

were heated with a CO2 laser. The basalt whole-rock samples were run on a VG 1200b mass spectrometer, which did not use a CO2 laser. All other minerals were run on both machines, and a resistance furnace instead of a CO2 laser was used to heat the samples.

Results

Geomorphology. The Nez Perce basin is an elongate basin, 17.4 km long and only 5.3 km wide, with a northwest-southeast orientation (Fig. 2, Fig. 7). The western basin margin forms the north-south divide between the Jefferson Valley to the east and the Divide Valley to the west. At the eastern basin margin, Nez Perce Creek is confluent with the Big Hole River in the Jefferson Valley. The northeastern basin margin extends from the northwest to the southeast and parallels the Rochester fault to the north. The southwestern basin margin parallels the McCartney fault to the southwest.

The topography within the basin appears to be more controlled by structure than by stream erosion in the western and central portions of the basin. Here, broad lowlands separate the north-south oriented ridges. In the western portion of the basin, the ridges and lowlands have relatively high relief, and gulleys incise the escarpment between a ridge of Neogene gravels forming the basin divide and the adjacent lowland. Small colluvial fans of locally derived material are present along some of the steep slopes. In the central basin, the ridges and lowlands have relatively low topographic relief. Archean (ca. 3.2 ba) metamorphic rock areas, some of which have a thin veneer of Miocene gravel, underlie the low ridges. Here the Nez Perce channel and its tributaries are incised into the ridges. The intervening lowland is a broad, flat area of Holocene/Quaternary alluvial sediment where the channels are not incised.

In the southwestern section of the New Perce drainage basin, the creek incises the Cenozoic gravel deposits. The incision forms a narrow valley with no floodplain in the upstream portion of this section. Near the confluence of Nez Perce Creek with the Big Hole River, the floodplain becomes wider than upstream and includes two terraces. The oldest terrace is 45 m above the present channel and appears to be a strath terrace (an erosional terrace formed by a stream down-cutting) formed on the Miocene gravel. Inset into the high terrace is a younger depositional terrace 10 to 15 m above a 90-m wide floodplain.

Stratigraphic Units. The following is a discussion of the various units found within the basin, listed from youngest to oldest, based on the field relationships. Each unit is given an informal name and a two- to four-letter abbreviation based upon the unit's age and geomorphic position. Cenozoic units, including four gravel units, basalt and rhyolite flows and intrusions, and a rhyolite tuff, are the focus of this thesis and are discussed in detail. Older Archean units are presented but not discussed.

Holocene channel deposits (Quaternary active channel, Qac) are comprised of well-rounded to angular clasts up to 17 cm in diameter (Appendix A) that are derived from the modern drainage basin. The channel deposit includes quartzite and sandstone clasts, probably from the Proterozoic Belt Supergroup, and gneiss gravel fragments from the local Archean bedrock (Fig. 3). The deposit is found throughout the basin within the active channel (Fig. 7). The gravel has a sand matrix and is interbedded with garnet-bearing coarse sand. The unit has a minimum thickness of 1 meter.

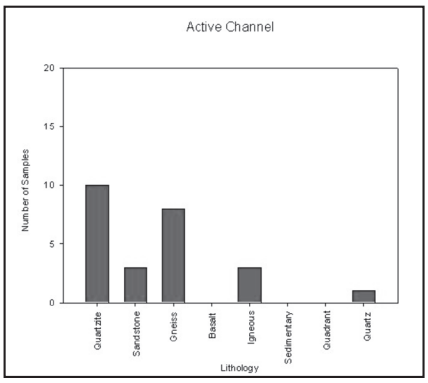

Figure. 3 Graph showing distribution of lithologies found in the active channel.

Holocene alluvium in stream valleys but beyond the present channel (Quaternary floodplain, Qfp) includes well-rounded to angular small clasts up to 5 cm in diameter that are derived from the modern drainage basin. Sand dominates the deposit and includes beds of sand and beds of gravel with a sand matrix (Fig. 4). This deposit is found in the downstream map area, where the valley floor is wide enough to include a floodplain, and in small (a few meters wide) deposits in the northern map area, where the topography is flat adjacent to the active stream channel (Fig. 7). The unit has a minimum thickness of 5 meters, based upon cutbanks of the stream channel.

Holocene/Quaternary alluvium that covers broad valley floors (alluvial sheet deposit, Qad) includes well-rounded to angular clasts up to 2.5 cm in diameter. The gravel fragments include small pebbles of red, pink, and brown quartzites, probably of the Proterozoic Belt Supergroup, well-cemented sandstone clasts, and fragments of local Archean gneiss. This unit forms broad, relatively flat surfaces that are locally adjacent to modern channels in the central portion of the drainage basin and are wider than most of the floodplain in the downstream portion of the basin (Fig. 7). The unit has an unknown thickness but is estimated to be a minimum of 1-5 meters thick based upon cutbanks exposed in the stream channel.

Holocene angular cobbles of rhyolite up to 6 inches in diameter are present on slopes surrounding a rhyolite outcrop (Quaternary colluvium, Qc) in the west-central portion of the drainage basin (Fig. 7). The deposit is of limited extent and is generally less than 5 meters thick.

Miocene well-rounded to sub-angular cobbles generally ≤ 20 cm in diameter form a terrace 45 m above the floodplain along the downstream portion of the Nez Perce Creek (Miocene terrace, Nt) (Fig. 7). The unit includes cobbles of Proterozoic Belt Supergroup quartzite, Archean gneiss, and sandstone. This deposit is similar lithologically to the Miocene divide gravel unit (see below), but the presence of Archean gneiss clasts in this unit and its position forming a terrace of Nez Perce Creek indicate that the deposit and the geomorphic surface are younger than the Miocene divide gravel unit that underlies the uplands. The unit has a minimum

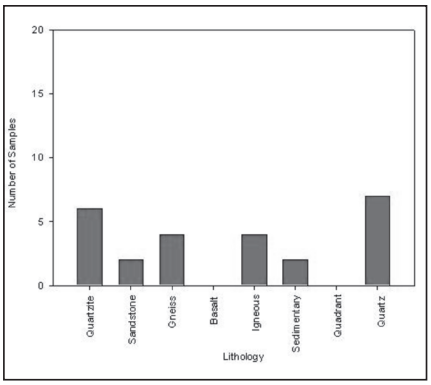

Figure. 4 Graph showing distribution of lithologies found in the floodplain.

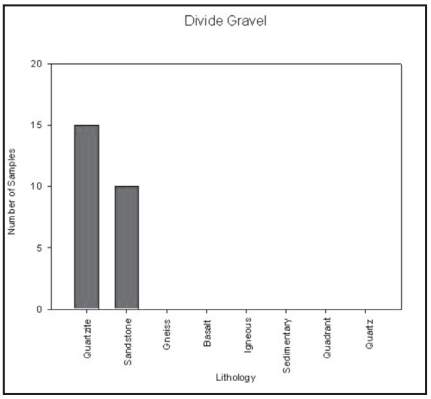

Figure. 5 Graph showing distribution of lithologies from the divide gravel unit.

thickness of 45 m.

The Miocene divide gravel (Ndg) includes well-rounded clasts up to 45 cm in diameter, with a mean diameter of 22 cm. The clasts are mostly brown, red, pink, and purple quartzite clasts and well-cemented sandstone fragments, probably from the Proterozoic Belt Supergroup. Gneiss clasts from the local Archean metamorphic rocks are absent or are very low in abundance (Fig. 5). This unit forms the western divide of the basin and extends to the east as an upland deposit that caps some ridges in the central part of the basin (Fig. 7). It has a minimum thickness of 170 meters. Gneiss clasts from the local Archean metamorphic rocks are absent or are very low in abundance. The cobbles are up to 30 cm in diameter and have a mean diameter of 20 cm, similar to divide gravels, but a small percentage of the gravel clasts are broken, which increases the mean angularity of the deposit. This subunit was previously mapped as a separate geologic unit with a thickness of 30 m (O'Neill et al., 1996). In the current study, the gravel is included with the divide gravel unit, suggesting a minimum thickness of 170 m, the same as that of the divide gravel.

The lowest gravel deposit exposed in the western portion of the map area is an Eocene debris-flow deposit (Edf) (Fig. 7) that includes subangular to rounded cobbles and boulders up to 4 meters in diameter within a finer matrix. The large clasts include the same lithologies as the younger Miocene gravels (Proterozoic brown, red, pink, and purple quartzite clasts and well-cemented sandstone fragments) and also include clasts of Pennsylvanian Quadrant sandstone and Eocene basalt, which are not found in any other gravel unit (Fig. 6). The thickness of this unit is approximately 40 meters.

Eocene basalt (Eb) flows are found along the western border of the drainage basin, interlayered with the debris flow deposit (Fig. 7). These extrusive basalt flows are very weathered and include phenocrysts of biotite. The minimum thickness is estimated to be 10 m, based upon the outcrop height on slopes.

A gray Eocene rhyolitic tuff (Et) weathers pink and has rounded quartzite and limestone fragments and angular gneiss and pumice fragments up to 5 cm in diameter in a fine-grained matrix. It underlies the Miocene debris flow and overlies the Archaen gneiss. The tuff is at least 13.5 m thick but is found in only one isolated location along a gulley in the northwestern portion of the drainage basin (Fig. 7).

The Eocene rhyolite (Er) has a purplish-gray to pinkish-gray matrix with phenocrysts (included minerals) of hornblende, sanidine, quartz, plagioclase, and biotite. It also displays distinctive chalcedony-filled cavities. The rhyolite outcrop occurs on the east-central border of the drainage basin and intrudes into Archean gneiss (Fig. 7). Previous K-Ar dates on the rhyolite, between 47 and 51 ma (Hanneman and Wideman, 1991), are consistent but not as precise as the Ar40-Ar39 dates reported in the current study (Table 1, Appendix B). The minimum thickness of this unit is estimated to be 25 m based upon outcrop elevation above the surrounding topography.

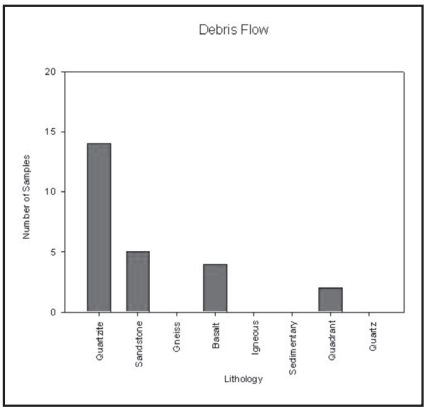

Figure. 6 Graph showing distribution of lithologies from the debris flow unit.

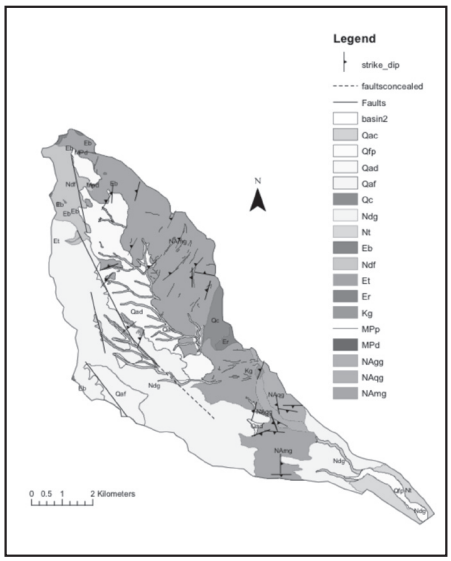

Figure. 7 Geologic map displaying all units. Faults represented by black lines.

Structure. Faults within and adjacent to the Nez Perce basin are the dominant control of the present landscape. The mapped faults in the study area are all within the gravel units of the western side of the drainage basin divide, except for one large fault that trends north-south in the middle of the basin and separates the Miocene gravel units from Archean gneiss.

The faults within the gravel units were initially identified on satellite imagery (Google Earth images), in aerial photographs, and in the field as north to north-northeast lineaments that separate blocks of different elevations. Mapping confirmed that the gravel unit that forms the surface of the blocks is the same lithologic unit, the Miocene divide gravel, though at a different elevation. The block margins are linear, and the block surfaces are relatively flat but do not necessarily slope down toward the basin. Streams do not drain all of the lower-elevation blocks, indicating that these low topographic features are not due to fluvial erosion. One of the blocks does have minor drainage that crosses it, but the drainages are very small ephemeral stream channels and are out of scale compared to the width of the block, which is close to 300 m.

Movement along the faults was generally normal (vertical). A vertical offset of up to 30 m is estimated using the relief between adjacent blocks. The down-faulted blocks have a veneer of late Quaternary gravels that is missing on the high topographic blocks, indicating that the faulting predates the late Quaternary. The offset of the Miocene divide gravel indicates that faulting postdates the middle Miocene. An alluvial fan at the base of the divide gravel in the southwestern map area shows no evidence of faulting within the fan but has accumulated on the downthrown side of a normal fault and post-dates the faulting, probably forming as a result of increased topographic relief.

Ages of Volcanic Rocks. Four igneous units in or adjacent to the map area that include basaltic and rhyolitic volcanic flows, rhyolitic pyroclastic debris, and basaltic intrusions have Ar 40/Ar 39 dates of ages that overlap and range between 47.5 to 49.9 ma (Table 1). This mapping and dating indicate that volcanic activity was widespread, though perhaps not volumetrically important, within this small geographic area during this relatively brief interval. A rhyolite flow is dated 47.9 ± 0.6 to 49.25 ± 0.29 ma, which overlaps the age of the rhyolite tuff, dated 48.5 ± 0.2 to 48.84 ± 0.17 ma, suggesting that the lava flow and the pyroclastic eruption are related in time and space. Basalt intrusions and flows have dates ranging from 47.5 to 49.7 that are statistically the same as those of the rhyolitic eruptions.

The dated volcanic debris in association with the debris flow unit allows the age of that debris flow unit to be closely bracketed because dated units underlie and intrude the debris flow. Six dates on single grains (sandidine and biotite) from the rhyolitic tuff underneath the debris flow range from 48.5 ± 0.2 to 48.84 ± 0.17 ma and provide a maximum age of 49.01 ma for the debris flow. Unfortunately, a basalt flow interbedded with the debris flow was too weathered to date. Three whole-rock dates on basalt dikes that crosscut the debris flow range from 48.9 to 47.5 ma and provide a minimum age for the debris flow, indicating that the debris flow is older than 47.5 ma (see Table 1, Appendix B). An additional whole-rock basalt date on a flow beneath the divide gravel, but with no known relationship to the debris-flow unit which is missing at this location, is 49.2 to 49.7 ma. The similarity of the date from this flow to that of the nearby intrusions indicates that both volcanic events are probably related. The dating results are displayed in more detail in Appendix B.

Sample #	Rock Type	Low Age (Mill. Yrs.)	High Age (Mill.Yrs.)
1	Basalt *	47.5	48.5 ± 0.1
2	Rhyolitic Tuff	48.59 ± 0.04	48.6 ± 0.12
3	Basalt *	48.7	48.7
4	Rhyolitic Tuff *	48.5 ± 0.2	48.84 ± 0.17
5	Basalt*	48.5	48.9
6	Rhyolite	47.9 ± 0.6	49.25 ± 0.29
7	Basalt	49.2	49.7
8	Granodiorite	80.5	80.5

Table 1. Results of the Ar 40/Ar 39 dating showing minimum and maximum ages and uncertainties. Asterisks denote samples used to bracket the debris flow.

Discussion

Gravel deposits are extensive in the western and eastern portions of the drainage basin and form a variety of geomorphic surfaces. Subdivision of the gravels based on the surfaces is difficult without some quantification of lithology and texture because faulting rather than stream erosion and incision may account for these surfaces. O'Neill et al. (1996) subdivided the upland gravels in the western portion of the basin into three units, listed in stratigraphic order: a Paleogene debris flow, a Neogene sedimentary gravel unit, and a Neogene fluvial gravel. The lowest unit, the Paleogene debris flow, forms the basin divide at the northwest margin of the basin and stratigraphically underlies the upper Neogene sedimentary gravel to the south along the rest of the western divide. The lower Neogene fluvial gravel underlies the secondary divide surfaces, but nowhere is there a clear stratigraphic relationship of this gravel with either an older debris flow or a younger Neogene fluvial gravel in the field, nor is there a clear lithologic difference between the two Neogene units. Based on geomorphology, O'Neill et al. (1996) recognized that the Neogene fluvial gravel was not a terrace deposit formed by incision. Rather, the stratigraphic position of the Neogene fluvial gravel is based on a lower topographic position of the Neogene sedimentary gravel than the Neogene fluvial gravel, and the Neogene sedimentary gravel is assumed to underlie the youngest Neogene fluvial gravel.

The results of the study indicate that the Neogene fluvial gravel is not a product of incision and thus is not younger than the Neogene sedimentary gravel. This conclusion is based on the fact that it is not inset within valleys, there are no stream channels in some of the topographically low areas mapped as Neogene fluvial gravel, and the surfaces slope at various angles and in different directions.

Though the lower gravels (Neogene sedimentary gravel) (O'Neill et al, 1996) are downslope from the divide gravel (Neogene fluvial gravel) (O'Neill et al, 1996), they have nearly identical lithologies and similar grain sizes, suggesting that they have a similar source (Fig. 2). The lithology of these units includes

Proterozoic quartzites and sandstones, probably from the Belt Supergroup, which is exposed in the Highland Mountains to the north. Archean gneiss is absent from both units, as is Quadrant Sandstone. Statistical analysis of the textural data using a One-Way Repeated Measures of Variance (ANOVA) test was used to compare the four major gravel units of this study. This test found a significant difference in grain size between each gravel unit, except those of the divide gravel and the lower gravel units, which are statistically the same (Fig. 8). If the older gravel had been reworked, the resulting lower gravel most likely would have resulted in a smaller grain size.

The results of the current study do not concur with those of O'Neill et al. (1996), who reported that the lower gravel (Neogene sedimentary gravel) was older than the divide gravel (Neogene fluvial gravel). When the lower basin gravel was exposed, either the divide gravel was not deposited and did not bury the lower basin gravel in these locations or it was subsequently stripped from these locations. Stripping of the upper Neogene gravel would require fluvial action, but no streams are present on this surface. It is also unlikely that two thick (between 150 and 300 m) tongues of divide gravel with steep slopes were deposited over the lower basin gravel.

The results of the current study indicate that the lower basin gravel and the divide gravel are parts of one unit separated by faults with some component of dip-slip movement. Lineament-bounded blocks of different elevations are slightly tilted at various angles to the south, and minor stream channels are offset where they cross the lineaments. The resulting topography is a series of small horsts and grabens that generally become lower in elevation to the east. The similar gravel lithology and texture associated with each surface support a faulting hypothesis. It is possible that the broken clasts could have been ruptured during faulting because more broken clasts were found downslope than upslope from the proposed faults. Faulting with either dip-slip motion (Reynolds, 1979) or oblique strike-slip motion (Rupple, 1993; Fritz and Sears, 1993) is abundant in the northern Basin and Range of southwestern

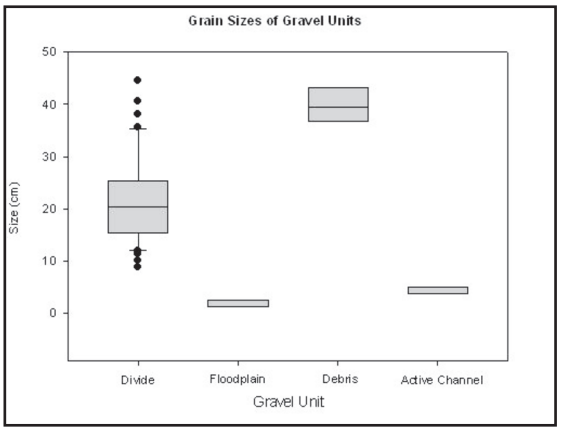

Figure 8. A comparison of the grain sizes of the four main gravel units.

Montana and likely occurs in the study area also.

Surface Erosion. The number of cobbles > 12.6 cm exposed on the ground surface was greater in the divide gravel than in the lower gravel unit, but analysis by a t-test showed no statistical significance. The exposure of more clasts in the divide gravel may simply be a result of wind and gravity erosion removing more fine-grained material on uplifted blocks than on down-dropped blocks, protected areas where fines may be preserved and even accumulate. A study was also performed within the basin of cobbles exposed on two northern and two southern facing slopes of the divide gravel unit. A greater number of cobbles was found exposed on the south slopes (average of 6.5 vs. average of 2), though this number was not shown to be statistically significant by a t-test. This finding may also be a result of wind erosion moving fine-grained material off the north-facing slopes at a more rapid rate than that off the south-facing slopes.

Source of the Gravels. The Alluvial Sheet Deposit was determined to be the youngest of the four major units. Its relatively small grain size (mean of 1.8 cm) and the presence of all lithologies found within the basin, including gneiss, quartzite, sandstone, basalt, and quartz, suggest that the Alluvial Sheet was deposited after the present basin was formed and the gneiss was exposed. Its source is entirely within the present basin.

Though there is some debate as to the physical relationship between the divide gravel and the lower gravel units, lithologic evidence suggests that they have a similar source. The presence of well-cemented arkose and red, pink, and purple quartzite implies that both units are derived in part from the erosion of the Belt Supergroup, which includes these lithologies (Kuenzi and Fields, 1971; Janecke et al., 2000). The Belt Supergroup is present to the northwest in the Pioneer Mountains and to the north in the Highland Mountains (Fig. 3). The Quadrant Formation is absent in the divide and lower gravel units and is exposed in the Pioneer Mountains but not on the south side of the Highland Mountains. Based on the absence of the Quadrant Formation, the probable source is the southern Highland Mountains to the north (Fig. 3).

The debris flow unit was determined to have a different source than the three younger gravel units. Quadrant Sandstone is present only in this unit, and there is no exposure of the Quadrant Formation on the southern side of the Highland Mountains to the north or the northern side of McCartney Mountain to the south; rather, the unit is exposed in the Pioneer Mountains and the Divide basin to the west (Fig. 3). The flow also includes some clasts of the local Archean gneiss, which underlies the debris flow and may have been incorporated within the deposit, suggesting that the debris flow was deposited at a different time than any of the other gravel units that do not include gneiss fragments.

Conclusions

The relationships among the four main gravel units in the Nez Perce Basin can be interpreted in several ways, each reflecting a different focus on topography, lithology, and/or grain size. The preferred interpretation for the current article focuses on the structural controls and concludes that the topography of the Nez Perce Basin is dominantly a reflection of Cenozoic structural and tectonic events rather than Quaternary fluvial processes. The lithology and grain sizes support the conclusion that faulting offsets the older two gravel units and controls the distribution of the younger gravel units.

From youngest to oldest, the four main gravel units in the study area are the Holocene channel deposit, the Quaternary floodplain deposit, the Miocene divide gravel, and the Miocene debris flow. The source of the channel and floodplain deposits is within the present basin and postdates the structural development of the basin, as determined by the presence of lithologies derived solely from within the present basin and a relatively small grain size (from 1 to 17 cm). In contrast, the source of the divide gravel is the Highland Mountains to the north, based upon the presence of well-rounded red and pink quartzites from the Belt Supergroup, which outcrops in the Highland Mountains. The source of the debris flow is the Pioneer Mountains to the west, based upon the presence of Pennsylvanian Quadrant sandstone, which outcrops in the Pioneer Mountains (Fig. 3). An additional gravel unit, informally termed the lower gravel, has been included in the divide gravel unit in this study, based on a statistically similar lithology and texture. This report concludes that small-scale normal faulting offset a single unit and created the elevation differences found within this unit. The changing lithologies, textures, and geomorphic positions of the gravels suggest substantial changes in streamflow patterns within the region, first between the Eocene and Miocene and subsequently between the Miocene and the Quaternary.

The Ar40/Ar 39 date of ca. 48 ma on basalt and rhyolitic tuff that underlie, are interbedded, and crosscut the debris flow unit indicates that the debris flow is middle Eocene. No igneous materials are associated with the youngest three gravel units, and Ar40/Ar 39 dating was not useful in providing more exact ages for the units.

Though the results of this study are limited to a small area, they give some insight into the structural history of that area. The presence of normal faulting within a single unit that has been determined to be of Miocene age suggests that extension was occurring at least 15 million years ago. This initial conclusion supports all three hypotheses proposed by Reynolds (1979), Rupple (1993), and Fritz and Sears (1993), who claim that the present-day basins and ranges were formed due to extensional events. However, the divide gravel unit was determined to correlate with the regional Sixmile Creek Formation, which is late Miocene to early Pliocene (ca. 5-16 ma). If this correlation is correct, data from this study best support the hypothesis of Fritz and Sears (1993), which claims that modern basin development began more recently than the middle Miocene. Without the faulting in younger units and a more regional examination, however, it is impossible to support one hypothesis over the others.

Acknowledgements

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Mentor comments: Professor Margaret Guccione speaks highly of Rose Feinstein's initiative in completing this research project. The Teaching Academy review committee readily recognized the scope and excellence of this work by awarding it one of the 2010 Undergraduate Research Awards.

Rose A. Feinstein, a proactive and very capable student, received funding for her project, ***Geologic Map of the Nez Perce Drainage***

***Basin**, Southwestern Montana, from the EDMAP program of the US Geological Survey (USGS). The EDMAP program is to provide money to students for mapping projects that will teach them mapping skills. Funding is very competitive and was fully funded, though only about 60% of the proposals are funded and only about 15% of the proposals are fully funded. It was quite an accomplishment! Not only did Rose produce the map, the only requirement for the grant, but she wrote a manuscript that described and interpreted the sedimentology, lithology, and structure of the units that are present in the map area and contributed a better understanding of the structural development of the mountains and valleys of southwestern Montana. Her project was strongly supported by the Montana Bureau of Mines and Geology and several of Bureau geologists visited her in the field to see her research. In addition, a U.S. Geological Survey scientist, intrigued with the project, volunteered to fly to Montana at no expense to the grant to help Rose sample the igneous rocks and offered the use of his lab in Reston, Virginia for Rose to prepare the samples for analysis, and analyzed the samples. This was a fantastic experience for Rose and the resulting dates are of interest to, have been requested by, and have been shared with the USGS and the Montana Bureau of Mines and Geology. The support, both financial and scientific, of the USGS and the Montana Bureau of Mines and Geology to this project done by an undergraduate, has been tremendous and demonstrates that the project has significant scientific value, far better than any mentor can extol.Rose's project has contributed to science in several ways. First she generated a number of dates on volcanic materials using a state-of-the-art dating technique in a state-of-the-art lab from an area where no dates of this caliber were available, she recognized structural elements that had not been recognized in prior mapping by using the gravel lithology, and she has applied this information to a more complete understanding of the development of the southern Highland Mountains and adjacent Jefferson and divide valley.*

Appendix A. General data collected from gravel units.

Unit	Location	Surface > 12.7 cm	5 Largest	Qtzite	SS	Basalt	Gneiss	Quad	Ig	Sed	Qtz
Ndg	N 45.33.514 W 112.33.607	9	19.05 24.765 22.86 16.51 15.875	18	4	1	0	0	0	2	0
Qaf	N 45.34.924 W 112.33.968	3	21.59 12.065 22.225 11.43 17.145	15	10	0	0	0	0	0	0
Ndg	N 45.34.015 W 112.33.197	3	25.4 15.24 20.32 13.97 30.48	16	9	0	0	0	0	0	0
Ndg	N 45.35.843 W 112.34.151	6	40.64 35.56 44.45 27.94 38.1	15	10	0	0	0	0	0	0
Ndg	N 45.32.924 W 112.31.501	3	25.4 22.86 27.94 19.05 21.59	10	14	1	0	0	0	0	0
Ndg	N 45.34.059 W 112.33.196	7	33.02 19.05 21.59 15.87 22.86	16	9	0	0	0	0	0	0
Ndg	N 45.35.467 W 112.34.225	6	30.48 17.78 24.13 17.78 17.78	13	12	0	0	0	0	0	0
Ndg	N 45.35.391 W 112.34.151	1	38.1 17.78 25.4 16.51 20.32	12	13	0	0	0	0	0	0
Mdf	N 45.36.479 W 112.34.129	11	40.64 39.37 45.72 35.56 38.1	14	5	4	0	2	0	0	0
Qaf	N 45.32.966 W 112.31.930	0	5.08 4.445 5.715 4.445 5.08								
Ndg	N 45.34.718 W 112.32.085	5	30.48 24.5 22.86 24.13 22.86	9	14	2	0	0	0	0	0
Qac	N 45.31.863 W 112.25.860	0	3.81 5.08 3.81 5.08 3.81	8	5	0	9	0	0	1	1
Ndg	N 45.31.353 W 112.25.209	4	27.94 15.24 33.02 16.51 25.24	12	13	0	0	0	0	0	0
Nt	N 45.31.214 W 112.25.080	0	2.54 5.08 3.81 2.54 3.81	9	12	0	1	0	0	1	2
Nt	N 45.34.067 W 112.31.717	2	38.1 14.605 15.24 17.78 13.97	15	10	0	0	0	0	0	0
Qfp	N 45.36.365 W 112.32.423	0	2.54 3.81 3.81 2.54 3.81	6	2	0	4	0	4	2	7
Qac	N 45.33.094 W 112.28.964	2	10.16 10.16 12.7 10.16 17.78	10	3	0	8	0	3	0	1
Ndg	N 45.32.814 W 112.29.216	2	12.7 11.43 10.16 8.89 12.7	11	11	1	1	0	0	1	0

Appendix B. Results of Argon dating.

	Sample #	Locationt NAD 27	Stratigraphic unit/position	Rock type	material dated	Dating method	Age	Uncertainty, 1 sigma	msd	Stage
1	071709-03	45° 33.651'N	Granodiorite intrusion - Boulder Batholith	granodiorite	biotite	single grain, total fusion	80.5	NA	large	late Cretaceous
		112° 28.941'W								
2	071709-04c	45° 33.479'N	Basalt flows that underlie divide gravel (Sixmile Creek Fm) south divide - Lowland Creek Field (Challis Fm)	Basalt	whole rock		49.2	NA		middle Eocene
2	071709-04e	112° 33.734'W		Basalt	whole rock		49.7	NA		middle Eocene
3	071709-02	45.34.311N	Rhyolite flow from volcanic "neck" - Lowland Creek Field (Challis Fm)	rhyolite	biotite, machine 1	single grain, total fusion	49.25	± 0.29		middle Eocene
3	071709-02	112.29.720W	Rhyolite flow from volcanic "neck" - Lowland Creek Field (Challis Fm)	rhyolite	biotite, machine 2	single grain, total fusion	49.01	± 0.3		middle Eocene
3	071709-02		Rhyolite flow from volcanic "neck" - Lowland Creek Field (Challis Fm)	rhyolite	biotite	single grain, total fusion	47.9	± 0.6		middle Eocene
4	071609-03a	45° 36.668'N	Basaltic dikes that intrude debris flow (preRenova Fm), north divide - Lowland Creek Field (Challis Fm)	Basalt	whole rock		48.9	NA		middle Eocene
4	071609-03b	112° 34.268'W		Basalt	whole rock		48.5	NA		middle Eocene
5	071609-05	45° 36.074'N	below debris flow (preRenova Fm) , bottom of tuff - Lowland Creek Field (Challis Fm)	tuff	sanidine	single grain, total fusion	48.6	± 0.2		middle Eocene
5	071609-05	112° 33.468'W	below debris flow (preRenova Fm) , bottom of tuff - Lowland Creek Field (Challis Fm)	tuff	sanidine	single grain, total fusion	48.5	± 0.2		middle Eocene
5	071609-05		below debris flow (preRenova Fm) , bottom of tuff - Lowland Creek Field (Challis Fm)	tuff	biotite, machine 1	single grain, total fusion	48.66	± 0.2		middle Eocene
5	071609-05		below debris flow (preRenova Fm) , bottom of tuff - Lowland Creek Field (Challis Fm)	tuff	biotite, machine 2	single grain, total fusion	48.84	± 0.17		middle Eocene
6	071609-02b	45° 36.849'N	Basaltic dikes that intrude debris flow (preRenova Fm), north divide - Lowland Creek Field (Challis Fm)	Basalt	whole rock		48.7	NA		middle Eocene
6	071609-02c	112° 34.284'W		Basalt	whole rock		48.7	NA		middle Eocene
7	071609-01	45° 36.001'N	below debris flow (preRenova Fm) , top of tuff - Lowland Creek Field (Challils Fm)	tuff	sanidine, small grain	single grain, total fusion	48.59	± 0.04		middle Eocene
7	071609-01	112° 33.753'W	below debris flow (preRenova Fm) , top of tuff - Lowland Creek Field (Challis Fm)	tuff	sanidine, large grain	single grain, total fusion	48.6	± 0.12	1.98	middle Eocene
8	071609-04e	45° 36.498'N	Basaltic dikes that intrude debris flow (preRenova Fm), north divide - Lowland Creek Field (Challis Fm)	Basalt	whole rock		47.5	NA		middle Eocene
8	071609-04a	112° 34.322'W		Basalt	whole rock		48.5	± 0.1	1	middle Eocene

TURNING THE CUP: THEMATIC BALANCE IN THE GREEK SYMPOSIUM

By Matthew Naglak
Department of World Languages, Literatures and Cultures

Faculty Mentor: Alexandra Pappas
Department of World Languages, Literatures and Cultures

Abstract

The concept of "nothing in excess" was an important one in ancient Greek life. The guiding principle of moderation and/or balance appears in poetry from the 7th to the 5th centuries BCE and has been extensively explored by scholars. My research project adds to this scholarly work by considering for the first time the relationship between moderation and the visual. That is, I explore whether and how this key Greek notion was expressed in the images that appear on pottery of the time period. More specifically, I focus on pottery used in the symposium, a politically-charged aristocratic male drinking party, and examine objects from the University of Arkansas ancient Greek pottery collection. Using these sympotic containers, I intend to demonstrate that the same critical themes of balance and moderation are expressed as visual counterparts to the poetic tropes. In this project, I examine how ancient painters used contrasting themes on opposite sides of a vessel to express the importance of choosing a moderate path. These contrasts included male/female, civilized/barbarian, and upper/lower class comparisons. In this grouping I also consider bilingual vases, so called for their similar scenes on either side, with one red-figure and the other black-figure. These pots reflect a balance in the artistic style itself through the use of opposite methods. This relationship is similar to the communication of the importance of physical balance found in other containers.

Introduction

The iconic Greek phrase "μηδεν αγαν," which translates as "nothing in excess," was inscribed in antiquity over the entrance to the Temple of Apollo at Delphi and represents the importance of moderation in ancient Greek life (Plato, *Charmides* 165a). Several common terms in the ancient Greek language were used to define the virtue of moderation, such as *metrios*, meaning moderate or of a middle condition, *to metron*, meaning the mean between two extremes, and *mesos*, defined as middling, moderate, or midway (LSJ 436, 442). Leslie Kurke, Ian Morris, and others have focused on moderation and its relationship to the poetry of the symposium. I, however, reframe the issue by focusing instead on the pottery, which was as integral to the symposium as the poetry performed there, as well as the interconnection between the concepts of moderation and balance. I suggest that these two notions were intertwined in the Greek mind, for to be a moderate man meant to negotiate a careful balance between undesirable extremes in everyday life. My work concentrates specifically on the messages of balance and moderation in the figural scenes depicted on the pottery used in the late archaic *symposium* (c. 520-480 BCE), a politically charged aristocratic male drinking party. In this context, I examine how the aristocrats received these messages by means of the method of thematic balance on the pot itself.

Messages of Moderation in the Symposium

The ancient Greek symposium, or drinking party, was an aristocratic adult male gathering that took place after dinner (Murray 6). It was an inherently private affair, taking place in the *andron*, or men's room, of a private house with between 14 and 30 men. The only women permitted were the *hetairai*, female "companions" who entertained the drinkers (Neer 106). The entire event was highly ritualized, beginning with the pouring of *spondai*, or libations, to Zeus and the Olympian gods, to the Heroes of old, and to Zeus Soter, or Zeus the Savior, as a reminder of the religious nature of the gathering (Lissarrague 1990a, 25-26). Afterwards, the obligatory mixing of water and wine took place, an important custom which identified the drinkers as true Greeks. Only barbarians drank their wine neat, disrespectful as they were of its power (Murray 6). The *symposiarch*, the master of the party, chose the ratio of water to wine as well as the number of *kraters*, the large vessels used to mix the liquids, which the drinkers consumed. The mixture varied from 3:1 to 5:3 or 3:2, but, in general, the wine was diluted by at least half. Once the wine was ready, the participants reclined on large *klinai*, or couches, with two or three men on each (Boardman 126). Numerous entertainers were usually present, including acrobats, flute-girls, and the above-mentioned hetairai (Jones 185-198).

The symposium was an important affair in the life of an Athenian aristocratic male. The small group of attendees at each event often created friendships and, perhaps more importantly, political alliances. The act of sharing a cup with companions generated bonds among group members; it was a symbol of both political unity and cultural identity (Davidson 1997, 40). It was also a time for reinforcing proper codes of behavior, such as the importance of living a moderate lifestyle. An aspiring politician was expected to be present and to partake of the available drink without consuming to excess. A "drink-lover" was defined according to the length of his periods of drinking as well as the chronic nature of his condition. In the 5th century BCE, the Athenian statesman Antiphon advised those seeking political office "to avoid being tagged a 'drink-lover' and being thought to neglect your affairs overcome by wine" (Davidson 1997, 150-151). Too much drink caused negligence and political idleness. The other extreme, that of drinking only water, was no better: a "water-drinker" was considered anti-social, unsympathetic, and a dispassionate speaker. As Cratinus (5th century BCE) stated in his play the *Wine-flask*, "A water drinker would never give birth

to anything ingenious" (Davidson 1997, 151). Thus, moderate behavior in the symposium was not achieved through complete abstinence from wine and pleasure but rather through a careful balance of extremes.

The significance of balance and moderation was transmitted to participants of the symposium in various ways. Lyric verse composed by the poet Theognis (6th century BCE) for performance during the drinking party overtly communicates the notion (translation and emphasis mine throughout unless otherwise noted):

αὐτὰρ ἐγώ, μέτρον γὰρ ἔχω μελιηδέος οἴνου,
ὑπνου λυσικάκου μνήσομαι οἴκαδ᾽ ἰών.
ἥκω δ᾽ ὡς οἶνος χαριέστατος ἀνδρὶ πεπόσθαι·
οὔτέ τι γὰρ νήφων οὔτε λίην μεθύων·
ὃς δ᾽ ἂν ὑπερβάλλῃι πόσιος μέτρον, οὐκέτι κεῖνος
τῆς αὐτοῦ γλώσσης καρτερὸς οὐδὲ νόου…
…ἀλλὰ σὺ ταῦτα

γινώσκων μὴ πῖν᾽ οἶνον ὑπερβολὰδην...

Moreover I, for I have the proper measure of honey-sweet wine,
will think of evil-ending sleep going homeward.
But I have reached the point when the most pleasing wine has been drunk by men;

being not at all sober nor being excessively drunk;

but whoever exceeds the proper measure of drinking, he no longer is master of his tongue nor mind…

but you understanding these things

do not drink wine excessively...(475-487)

Poetry, however, was not the only medium used; I propose that the images on vessels central to the sympotic process were utilized as well. With a few exceptions, I analyze various images appearing on *hydriai* (sing. *hydria*) used for holding water, *amphorai* (sing. *amphora*) used for storing and holding wine, kraters for mixing the two together, and *kylikes* (sing. *kylix*), cups for drinking the mixed wine. The scenes I study appear both in the interior of the kylix, known as the *tondo*, and on the exteriors of the various vessels, with pictures painted in either red-on-black, called *red-figure*, or black-on-red, called *black-figure* (Clark et al. 72, 138). In this work, I examine how ancient painters used contrasting themes on opposite sides of a vessel to express the importance of making moderate choices. These contrasts include male / female, civilized / barbarian, and upper / lower class distinctions. In this grouping, I also consider *bilingual* vases (Clark et al. 72), containers with a red-figure image on one side and a black-figure painting on the other. These pots, painted with opposite methods, reflect a balance in the artistic style itself.

In the 6th century BCE, the pre-Socratic philosopher Thales lived in the city of Miletus in Asia Minor. He was one of the Seven Sages of ancient Greek tradition, and Aristotle considered him the first true Greek philosopher (*Metaphysics* A 983b18). In his *Lives of Eminent Philosophers*, written in the 3rd century CE, Diogenes Laertius attributed to Thales (via the writer Hermippus from the 4th century BCE) the statement:

τριῶν τούτων ἕνεκα χάριν ἔχειν τῇ Τύχῃ·
πρῶτον μὲν ὅτι ἄνθρωπος ἐγενόμην καὶ οὐ θηρίον,
εἶτα ὅτι ἀνὴρ καὶ οὐ γυνή,
τρίτον ὅτι Ἕλλην καὶ οὐ βάρβαρος.

that because of three things he gave thanks to Fortune;
first that he was born a human and not a beast,

next that [he was born] a man and not a woman,

third that [he was born] a Greek and not a barbarian (1.33).

Here is concrete evidence of the contrast between what is "ideal" and what is "other" from an author contemporary with the corpus of pots under consideration here. On one side is a human Greek male; on the other is a beast, a woman, a barbarian. Thus, it is not a surprise that through these same terms the messages of balance and moderation were often expressed on sympotic pottery. I suggest that a second popular method of expressing this contrast was by using thematic balance, where one side of the pot expressed the Athenian ideal and the opposite side the unwelcome "other."

Thematic Balance: Man vs. Beast

The beastly "other" was often represented by the satyrs, the wine-loving followers of Dionysus. Indeed, painters often used satyrs as examples of immoderate behavior, and they are one of the most popular subjects of Greek vase painting, being found in mythological and sympotic scenes and as the companions and servants of Dionysus (Walsh 16). The ears and tail of a donkey, a snub nose, a bald forehead, a bushy beard, and a large, erect penis characterize these half-man, half-animal beings (Mitchell 156). Although in some instances satyrs are depicted as playful and good-natured, the great shortcomings of the animalistic creature make the satyr a common foil for the Athenian male.

Along with drunkenness and its accompanying idleness, satyrs add unquenchable lust to the list of shortcomings invited by excessive drink. François Lissarrague states, "Satyrs are characterized by an exuberant, excessive, and inexhaustible sexual energy, comparable only to their appetite for wine" (1990b, 65). In contrast to the form of these beasts, Aristophanes describes the ideal youth in the *Clouds*:

ἕξεις ἀεὶ
στῆθος λιπασρόν, χροιὰν λαμπράν,
ὤμους μεγάλους, γλῶτταν βαιάν,
πυγὴν μεγάλην, μόσθην μικράν.

You will always have

a shining chest, radiant skin,

large shoulders, a humble tongue,

a large ass, a small penis (1011-1014).

While surely a joke of the comic poet, this poem nonetheless indicates the ideology that to have the enormous penis of a satyr was not in accordance with ideal aristocratic qualities. In

most Greek art, the male penis is short, thin, and straight, with a scrotum of an average size (Dover 125-35). Thus, the enlarged phallus, almost always exaggerated, becomes the most obvious representation of the satyr's licentious and drunken nature. The ithyphallic satyr becomes a laughable creature, not a model one. The purpose of the satyr was to imitate and distort the acts of humans, and therefore for a human to act like a satyr was disgraceful.

A red-figure krater by the Nikoxenos Painter (525-490 BCE) is a visual manifestation of Thales' first reason to be thankful to Fortune (Figure 1; *ARV*^{2} 221.14, Mitchell 187). On side B (the lower in my image), athletes are training for the pentathlon. From right to left, there are a trainer, two boxers, an *akontist* (javelin thrower), an *auletes* (flute player), another akontist, a *diskobolos* (discus thrower), another auletes, and a runner (Mitchell 188). On side A, a parallel scene is composed entirely of satyrs. The beasts are practicing the discus, javelin, long jump, and boxing. There are also two trainers and a flute player. Side A is a parody of B, and reading the two together leaves the impression that the ideal Greek male should be strong, capable, and athletic, necessary traits in sport and in battle. The human trainers each hold the forked stick symbolic of their position; among the satyr athletes, the trainers are carrying around giant dildos, evidence of their sexual nature. Further, the satyrs train with full erections, something never shown in the painting of an average male athlete. In fact, the penis of an athlete is usually tied down with what is known as a *kynodesme* in order to prevent erections and provide comfort during competitions (Mitchell 188).

Figure. 1 Krater, Attic RF; 525-490 BCE

Satyrs were a beastly foil for the ideal Athenian aristocrat. All knew their voracious appetite for wine and sex. Thus, their presence in the symposium was common, and their appearance on this krater is informative. The krater itself announces and reinforces the message that it is necessary first to mix water and wine to the proper proportion in the krater before consumption can occur. If anyone drinks too soon, before a balanced mixture is ready, he may quickly transform from the ideal male Greek on the first side of the krater to the sex-hungry satyr on the opposite side. Each time he looks at the krater, the reveler is able to see either what he ideally should be or what he may become if he is unable to control his habits.

I find this same contrast on an Attic red-figure kylix from 500-490 BCE. On one side of the kylix, a drunken youth rides on top of an inflated wineskin, as if it were a horse, while blowing into a drinking horn. The normative image, of which this youth is a parody, is on the opposite side of the cup (Figure 2; *ARV*^{2} 50.187; Mitchell 180). Here, a youthful warrior is departing for battle. A large shield lies near his feet, and he blows into a war trumpet to announce the departure. Again, the differences between the desired and the overindulgent are clear. The focus is living a lifestyle pleasing to the city. With too much wine, the drinker becomes a laughingstock, spending his time blowing into drinking horns and sitting on wineskins instead of marching to war for his city. In the end, an aristocrat who acts in this manner is no better than an uncivilized barbarian or satyr, his laziness and passivity leaving his city vulnerable to the physical and moral attack of external enemies.

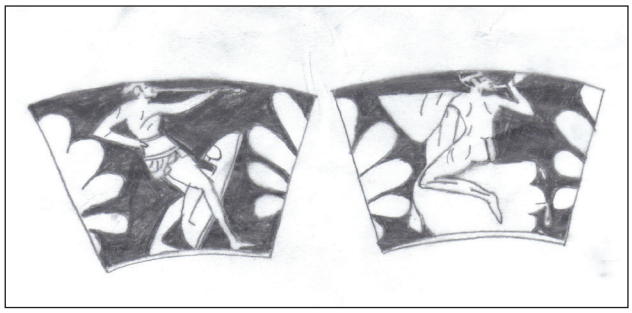

Figure. 2 Cup, Attic RF; 500-490 BCE

Thematic Balance: Man vs. Woman/ Greek vs. Barbarian

The second reason for Thales' thankfulness was that he was "a man and not a woman." Women joined satyrs in their inferior "otherness." From the Greek poet Hesiod onward, men believed women to be polluted both morally and physically (*Works and Days* 753-755, Carson 136). Indeed, it was generally accepted that women were more susceptible to their desires than men and felt no need to control themselves. Beyond this sexual excess, men also feared the "passivity" of behaving in a womanish manner. Kenneth Dover demonstrated that in ancient Greek culture the penetrated sexual partner was considered the weaker one. This place was usually regulated to woman and slaves, while the male confirmed his power as the penetrator (100-102). Beyond this, however, for a male to act in a passive way during sexual relations was to give up his masculine status and denigrate himself to the inferior female (Skinner 14) Thus, because of this passive nature, women were not capable of achieving the same ideal as active men were. For a man to be compared to a woman was therefore degrading and suggested a moral and physical pollution that would lead to the loss of political power.

A red-figure *pelike* (pl. *pelikai*), 475-425 BCE, in the University of Arkansas collection demonstrates the distinction between male and female (Figure 3; Arkansas 57-24-21, *ARV*^{2} 1063.1). A pelike was a jar used mostly for storing oil and wine for later use (Clark et al. 127). In general, it was wide-mouthed and continuously round from its neck to its foot, and it had two vertical handles. Side A of the University of Arkansas vessel shows two mounted figures with leather cuirasses, linen skirts, and war helmets riding to the right. Sir John Beazley identified these riders as Amazon warriors due to their similarity to figures on other pots

with inscribed Amazonian names (Maule 89). On the opposite side of the pelike are three beardless, cloaked Athenian males deep in conversation. The figure on the far left holds a staff and is facing the other two, while the one on the far right gestures with his hand for emphasis. The center figure has his arms entirely within his cloak and seems to be listening to the other two talk.

Figure. 3 a-b: Pelike, Attic RF; 475-425 BCE (University of Arkansas Collections Museum Number 57-24-21, photographed by the author)

I suggest that the sympotic drinker would have recognized both a male-female and a Greek-barbarian opposition on this vessel. The actions and dress of the figures on each side indicate their different roles. The Amazons are warlike, barbaric women, ready for battle. They rush in on their horses, emphasizing action and physicality over consideration and assessment. They are women playing the active role of men, making them innately strange. This role upsets the balance between the sexes in the social and political landscape of the Athenians. The Athenians on the other side, in contrast, wear their normal cloaks, stand tall, and appear deep in conversation. This vessel suggests that, while certainly capable in battle, the Athenian male had to be thoughtful of all the possibilities and ramifications of a situation as well. Interestingly, the helmets of the Amazons are Attic in origin (Maule 89), which suggests that it is the noble Athenians who influence the barbaric other, not the other way around. This is a subtle message of reassurance to the viewer of the certain victory of the Athenians over any enemy. In the context of the symposium, the Athenian aristocrats represent a gathering filled with intellectual exchanges, songs, and entertainment. The Amazons, on the other hand, are a warning against immoderate behavior. The drunken one himself wages a war on the ideals of the city, just as the Amazons once did (Plutarch, *Theseus* 19), opens himself to the moral and physical penetration innate to women and pathics.

The images on the neck of a red-figure krater by Euthymides (510-490 BCE) again involve a contrast with Amazons (Figure 4a-b; *ARV*² 28.10; Neer 109). On side A is a battle between the Greeks and the Amazons. Herakles, appearing in the middle of the battle wearing his signature lion skin, is fighting on the side of the Greeks. Other one-on-one battles occur around him between Greek hoplites and Amazonian warrior women. On the opposite side of the vessel, there is a very different scene: a relaxed symposium. Six men are reclining on a patterned mat, each with a pillow on which to rest his elbow. On the far left, the word *khaire*, "rejoice," appears above two drinkers raising their cups.

The most obvious contrast on this vessel is between the Amazons on one side and the sophisticated Greeks on the other side. One is unsettling, one normative, as shown in Figure 4a-b. I further suggest that each side represents a certain aspect of the battle between the exemplary Greek and unacceptable barbarian influences. The physical battle on side A is the clearer conflict. Warriors from each side are fighting to the death to see who the winner will be. Herakles, one of the most famous Greek heroes, symbolizes all that is Greek. In the image, he has just knocked down an Amazon warrior and is about to finish her off. Thus, assurance is given regarding the mastery of the Greek over the barbarian and the male over the female.

On the opposite side, there is a second battle, but this is one of moderation rather than of arms. The two men on the far left are wearing Lydian hats, representing barbaric influences in the symposium. Again we see a battle between what is Greek and what is "other." It is correct for the Athenian aristocrat to act properly, to drink moderately, and not to overindulge. The positive qualities of the noble should overcome the desires of the barbarian, just as Herakles overcomes the Amazon. The word "rejoice" is a call to drink and to enjoy the symposium, but the Lydians beneath it serve as a reminder not to overdo and through intoxication resemble a barbarian.

A debated red-figure *oinochoe* (pl. *oinochoai*) from c. 466 BCE provides another picture of the Greek-barbarian contrast (Figures 5a-b; Hamburg 1981.173; Neer 166). An oinochoe, which translates as "wine-pouring vessel," was a pitcher or jug used for serving wine in the symposium (Clark et al. 118). Here, a single figure stands on either side: side A shows a Greek warrior and side B a barbarian. The Greek is completely nude except for a cloak tied around his neck and is striding quickly to the right. In his right hand he holds his erect penis, while he stretches out his left hand towards the barbarian on the opposite side. The barbarian has a large beard, is wearing tight, patterned eastern clothing, and has a quiver hanging from his arm. He is bent over, with his buttocks spread toward the approaching Greek, and holds his hands over

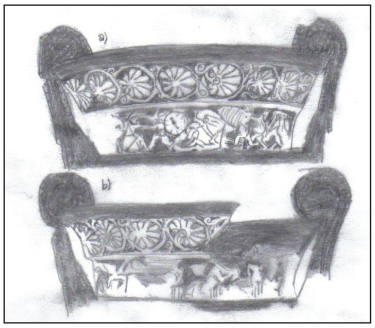

Figure. 4 a-b: Krater, Attic RF; 510-490 BCE

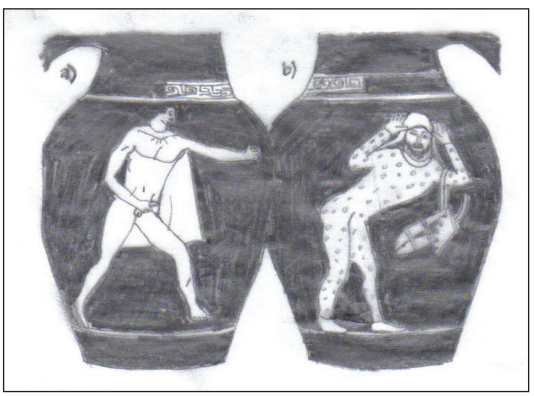

Figure. 5 a-b: Oinochoe, Attic RF; c. 466 BCE

his head in a gesture of surrender or surprise. He faces outward as if addressing the external viewer. The barbarian's words inscribed between the two figures, *Eurumedon eim[i] kuba[de] esteka*, "I am Eurymedon; I stand bent over" (Mitchell 85), appropriately describe his position.

Multiple interpretations of this vessel are possible (Neer 164, Davidson 1997, 170, Dover 100-102). I, however, will focus on the depictions as another example of the triumph of the Greek over the barbarian. Here, the Greek warrior is the active figure and the barbarian the passive one. The Greek is the powerful, idealized penetrator, the barbarian the weak, effeminate penetrated. The barbarian is thus as much an example of effeminate weakness as of failure in battle. Again we have an example of the power of the active over the passive. The name of the barbarian, Eurymedon, provides more information about who he is. His name can be broken into two ancient Greek words: *eurus*, meaning "wide," and *Medos*, a term referring to the Persians (LSJ 233). Thus, the name is play on words, designating the barbarian as a "wide (ass) Persian," whose stance is a visual representation of his name (Mitchell 86). I see the oinochoe, then, as a specific representation of the cultural pride achieved due to the triumph of the strong, masculine Greeks over the invading passive Persians, as well as an amusing dirty joke.

There is still more here, however, when we consider the immediate historical context. At the time of the vase's production, the Athenians were at the height of their power after defeating the great threat posed by the Persian barbarians. Indeed, between 468 and 465 BCE, the Greeks won a great victory over the Persians at the mouth of the river Eurymedon in Pamphylia (Thucydides, *Peloponnesian War* 1.100; Mitchell 85). At this site, both land and sea battles took place at the same time, with the Greeks winning on both fronts and destroying over 200 boats. This vase is a celebration of that victory, and any aristocrat who had fought in the battle certainly would have approved of the production of this vase and the messages it sends. One on side of the vessel is a strong, masculine, ideal Greek, while on the other is a passive, cowardly Persian. As wine was poured into his kylix from this pitcher, the images the Greek man saw would remind him of the victory and the virtues by which that victory was achieved. Moderation will lead to victory in both war and politics, while overconsumption could result in the loss of one's elite status and would have resulted in defeat against the Persians in that great battle.

Related to the concept of foreign barbarianism is the institution of slavery in Athens. The notion that it was not right for Greeks to enslave other Greeks became established very early. Indeed, the members of the Delphic *amphictiony*, or league to defend the sanctuary, in their first meeting swore not to remove the members of any state in their federation from their city (Aeschines, "On the Embassy" 115). Later, Herodotus stated that the people of Methymna on Lesbos enslaved the citizens of Arisba, even though they were of common ancestry, which suggests how unusual a practice this was (*Histories* 1.151). Indeed, civil war between Greek city-states as a rule led to the exile or execution of the defeated, not their sale into slavery (Garlon 13). Even slavery due to debts became rare in Greek cities. Instead, it was decided that only non-Greek barbarians were "naturally" fitted for a life of servitude to their Athenian masters (Garlon 120). By the time of Plato and Aristotle, the idea was fully entrenched. Plato stated that other Greeks should not be enslaved in wars (*Republic* 5.471a), and Aristotle agreed with the concept of the "natural" slavery of barbarians (*Politics* I).

Thematic Balance: Master vs. Slaves

Due to the number of slaves in the Athenian community, it is not surprising to find depictions on sympotic ware of slaves performing their duties in the symposium. Working slaves on one side of a vessel often contrast the upper-class Athenian revelers on the other. A red-figure *stamnos*, an alternative to the krater for mixing wine (Clark et al. 146), signed by the painter Smikros in the late 6th century BCE provides an example of this contrast (Figure 6a-b; *ARV*² 20.1; Neer 88). On side A is a typical Athenian symposium. Each male participant reclines on his couch while a hetaira attends to his entertainment. On the opposite side, two male slaves make sure the supply of wine does not run dry. Each slave has an amphora from which he pours wine into a large central krater. Around the krater are various other sympotic vessels used for serving wine. There is a similar juxtaposition on a red-figure krater (Figure 7a-b; *ARV*² 1619.3; Neer 112-144) from c. 500 BCE. Painted by Euphronios, this krater also shows a fancy symposium on one side and youthful slaves fetching wine on the other.

Figure. 6 a-b: Stamnos, Attic RF; 510-500 BCE

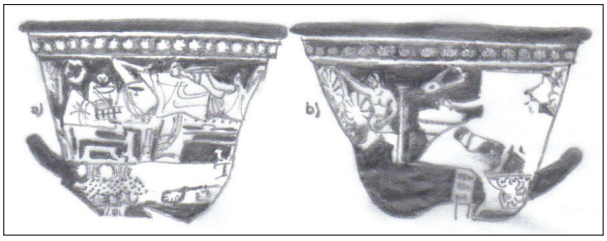

Figure. 7 a-b: Krater, Attic RF; c. 500 BCE

On both vessels we see a thematic balance between the citizen Greek and the enslaved foreigner. As slaves were nominally barbarians and barbarians were "natural" slaves, the Athenian aristocrat identified himself with the members of the symposium and saw his foil in the working slaves. As such, he would remember the traits and ideals that distinguished him as a Greek elite. The slave may have fallen into the class of the sexually passive, just as women did, and, indeed, elites commonly used their young slaves as sexual objects (Davidson 2007, 555). Thus,

the image of the slaves was also a reminder of the weakness and effeminacy associated with the slave class, traits a citizen male did not want associated with himself.

Bilingual Vases

Painters set up a balance of contrasting themes, however, not only through showing the ideal on one side and the "other" on the opposite, but also in the case of bilingual vases, a method which is used only in the last quarter of the 6th century (Cohen 2). As discussed previously, the two main decorative styles in Attic vase painting were black-figure and red-figure. Black-figure pottery appeared first, derived from Corinthian pottery techniques in the late 7th century BCE. Red-figure was a creation of Athens herself, invented during the last quarter of the 6th century BCE (Cohen 2). The older method, however, was not immediately abandoned despite the advancement of this new technique. Indeed, early red-figure drawings appear on bilingual vases, with black-figure on one side and red-figure on the other. In this way, the vases were said to "speak" the languages of both techniques (Clark et al. 72), although each side could be painted by a different artist (Cohen 20). The extreme nature of these pots reflects the extreme contrasts in the political systems fighting for power at the time: rule by the many vs. rule by the few.

The period during which bilingual vases were popular (525-500 BCE) was a time of great political change in Athens. The tyranny of the Peisistratids fell in 510 BCE and ushered in the beginning of Athenian democratic reforms under Cleisthenes in 508 (ODCW 90). Even before this upheaval, however, change was being sought throughout the Athenian city. Citizens were unhappy with the status quo, both politically and artistically. One way this feeling manifested itself was through new methods of creativity and invention in vase painting (Cohen 18). Artists first used red-figure painting during this period, and it soon became the prominent style for all pottery. With this new style, the concept of the bilingual vase was born.

Amphorae and kylikes were the two main vase shapes to which the bilingual painting technique was applied (Cohen 19). On bilingual amphorae, side A was executed in red-figure and side B in black-figure. Due to this arrangement, it was necessary for the viewer to rotate the vessel 180 degrees in order to tell that the artists had employed two different techniques in its decoration. The paintings on the bilingual drinking cups were different from those on the amphorae. A black-figure image was usually painted in the tondo, while the exterior decoration was entirely in red-figure (Cohen 23). The earliest bilingual cups were eye-cups, vessels with pairs of large eyes decorating their exteriors. Most of these eyes were male, although female and animal eyes do exist. Explanations for the popularity of these eye-cups vary. Some believe that they had the apotropaic function of warding away evil spirits, while others associate them with the eyes of Dionysus, the god of wine, or with masks worn by actors in the theater (Clark et al. 90). Indeed, all of these explanations could explain their appearance as a popular decoration on drinking cups in the symposium.

The painters of the earliest bilingual vases used the old and new methods in ways that would complement, not compete with, each other (Neer 22-23). In a few cases, similar scenes appear on each side of the same vessel, one in black-figure and the other in red-figure. This method is seen on an amphora from 515-510 BCE decorated by the Andokides Painter (side A) and the Lysippides Painter (side B), which shows Herakles driving a bull to sacrifice (Figure 8a-b, *ABV* 254.2, *ARV*^{2} 4.7; Cohen 30-31). On both sides, Herakles walks behind a large bull holding a red tether and a bundle of sticks for use in the sacrifice. The skin of the Nemean lion is on his back, and he drapes full wineskins over his arm. He also has a club, a quiver of arrows, a sword, and a bow, although the latter detail is shown only on side B. On side A, Herakles, the bull, and a small tree in the background all appear in red-figure; on side B, they are all in black-figure. Sketch lines are visible on both sides of the amphora, but it is not known how the artists painted such a similar design on each side (Cohen 29).

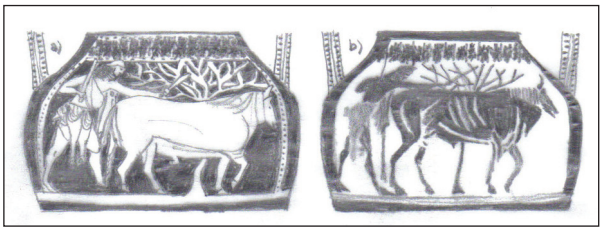

Figure. 8 a-b: Krater, Attic Bilingual; 515-510 BCE

With the images being so similar, the comparison of the old and new techniques must be the emphasis: "Neither side of the bilingual amphora is necessarily superior to the other; rather, the point seems to be that to have both versions, positive and negative, is desirable" (Neer 33). Here, the polar opposite images of the vase balance one another perfectly. Both sides are necessary to obtain this balance. In this way, I suggest, the artist sends the message of moderation to his viewers. Beth Cohen, however, reads the pot differently. To her, "the red-figure front is subtly emphasized over the black-figure back" (32). She sees the red-figure artist as seeking to reflect the details and movement of everyday life, while the black-figure artist is much more static and traditional. I suggest that this emphasis of the red-figure may be to show pride in the new Athenian method. Once again, a contrast is evident, but this time it emphasizes the Athenian over even the other ancient Greek city-states. Thus, the ideal Athenian is now the subject of emulation for all aristocrats, not the generalized Greek, and so the moderate qualities necessary for the Athenian elite to succeed become an even more vital subject for sympotic discussion.

The image on the remains of a bilingual eye-cup by the Andokides Painter (525-520 BCE) used the new method once again to emphasize what is Greek in contrast to what is barbarian (Figure 9; *ABV* 255.7, 256.21; *ARV*^{2} 5.14, 37.1; Neer 39). The tondo and the stem of the cup are unfortunately lost. The exterior decoration on this cup is unique in that it is half in red-figure and half in black-figure. The division occurs directly under the handles, where two Greek hoplites are battling over a fallen soldier. One hoplite is in red-figure, the other is in black-figure, and the fallen soldier is divided by the two styles. On the other ends of the cup, between the eyes, appear Scythian warriors. On the black-figure side, two archers stand on either side of a tree. They are both beardless and wear the hats and clothes of the Scythians. On the

opposite side stands a third beardless Scythian blowing a trumpet. He is wearing tight, patterned clothing and has a bow at his side (Neer 38).

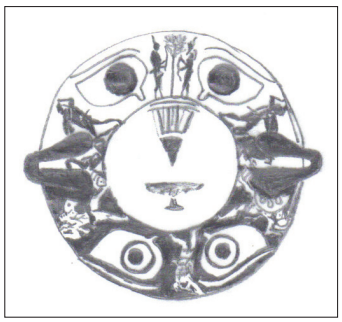

Figure. 9: Cup, Attic Bilingual; 515-510 BCE

Contrasts abound in this work, with the red-figure/black-figure distinction being only the first. I see the contrasting designs as a message about the importance of moderation to the Athenians. The Greek hoplites fight only on either side of the handles located in the middle of the cup where the drinker held it. The Scythians, meanwhile, stand on the extreme ends, where the wine poured into the drinker's mouth. Thus, I suggest that the hoplites are associated with the balance and moderation implicit in the handles of the cup, while the Scythians are equated with the over-consumption of wine. Further, the hoplites actively battle over a fallen warrior, fighting with their spears. The barbarians, on the other hand, are static figures, either inspecting their arrows or blowing a trumpet (Neer 40). Thus, their warlike inadequacies are clearly apparent to all. Finally, the Scythians stand directly between the "eyes" of the eye-cup. It is therefore the face and traits of the barbarian that the drinker must beware of each time he takes a drink. For as he lifts the kylix to drink, the face of the cup and of the barbarian replaces his own. At that moment, both the drinker and his companions literally lose sight of the ideal Greek hoplites near the handles, being left with only a warning of the barbarism connected with intemperate living.

Another bilingual eye-cup with the signatures of Epiktetos as painter and of Hischylos as potter from c. 520 BCE is much more intact (Figure 10a-c; GR 1842.4-7.23; Cohen 38-40). In the tondo is a horseman in black-figure. The feet of the horse do not touch the border of the tondo, giving the image a feeling of motion which the static rider does not reciprocate (Cohen 39). The young man is also wearing a red garland upon his head and holds the shafts of a pair of spears in his hands as he rides. Around the rider is the signature of the potter: *Hischylos epoisen*, "Hischylos made [me]."

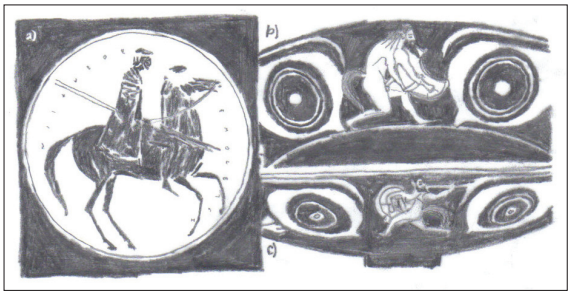

Figure. 10 a-c: Cup, Attic Bilingual; c. 520 BCE

As is the norm with bilingual eye-cups, the exterior decoration is in the newer red-figure. The eyes are large, with standard red pupils and white rings. On side A of the cup, a satyr walks between the eyes holding a crescent-shaped shield, known as a *pelta*, in one hand and a drinking horn in the other (Cohen 39). A red ivy wreath sits on his head, and the erection common to satyrs is readily visible. A second satyr strides between the eyes on Side B, moving quickly to the left with his body contorted backwards. He is blowing upon a trumpet (*salpinx*) and wears the lip band (*phorbeia*) commonly worn in the 6th century BCE (Cohen 40). He, too, carries a pelta slung over his right arm and wears a garland of ivy upon his head, but he is carrying an oinochoe instead of a drinking horn in his right hand. The inscription *Epiktetos* is behind the satyr on side A, while the word *egraspen* is on side B. Together these inscriptions spell out "Epiktetos painted me," although the word *egraphsen* is misspelled. In order for the viewer to read the name of the painter, he must turn the cup all the way around, which forces him to negotiate his own sense of balance as he rotates the cup in his hand.

I find that once again the figures contrast the ideal and the objectionable. The ideal can be found in the black-figure tondo: the young aristocrat calm and dignified in his posture even as his horse is galloping. His picture becomes visible as the drinker consumes his wine, a reminder of the moderation the reveler should keep in mind as he enjoys himself at the symposium. In contrast are the exterior red-figure satyrs. They each hold drinking vessels, but neither of the vessels is proper for moderate drinking, emphasizing the failure common to the beasts. Further, I propose that the external satyrs should be viewed as a compilation of the two figures on the inside of the cup: the man and the horse. All three humanoid figures wear a crown of red ivy upon their heads. On the other hand, the two satyrs are connected to the horse through their similar bushy tails and heads, with the long hair of the satyrs being similar to the mane of the horse. Thus the intermediate figure of the satyr here serves as a warning to the drinker who considers himself analogous with the elite young horseman: immoderation is closer than you may think. The ivy-wearing Athenian aristocrat might easily transform into the ivy-wearing satyr, especially during the symposium. It is important for the aristocrat to act moderately, keeping in check the actions that may lead to an unbalanced life, just as the horseman balances bareback upon his horse and controls its movements. Only through constant vigilance will he hold his place among the nobility and not succumb to an immoderate lifestyle.

An even more extreme version of a bilingual cup from c. 480 BCE again emphasizes the metamorphosis possible in the symposium (Figure 11; *ARV* 1534/9; Lissarrague 1990a, 58). On one side is the face of a white woman, and on the other is the face of a black woman. The anthropomorphism of vases was common in the ancient Greek world. In a literalizing moment, vases such as this one were created in the forms of both animal and human heads (Lissarrague 1990a, 57-8). Further, when a human head is modeled, it is never a white male's head. The only vessels found have been white women, black males and females, Asians, and satyrs. Each time the drinker partook of his drink, the face on the opposite side of the cup replaced his own to everyone around

him. For a single moment, he was no longer the aristocratic male but instead an image of the undesirable. Thus, in the case of both beasts and humans, the object of this vase type was to remind the drinker, and those around him, of what they were not. The cup defines the opposite of the ideal drinker, bringing him literally face-to-face with the "other," whether beast, woman, or barbarian, each time he took a drink.

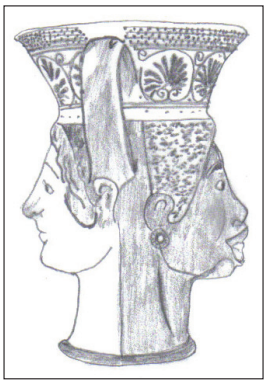

Figure. 11: Kantharos, Attic Bilingual; c. 480 BCE

Finally, I conclude this survey of balanced contrasting themes with a red-figured bilingual amphora from 515-510 BCE with the signature of Andokides as potter (Figure 12a-b; Madrid, Museo Arqueologico Nacional 11.008; Cohen 26-7). On side A, the god Apollo plays the lyre for Artemis, Leto, and Ares, who snap their figures to the music. On the opposite side, Dionysus stands in black-figure with two satyrs and two maenads flanking him. In his left hand, Dionysus holds a kantharos, his special drinking cup, by its stem, while with his right hand he holds a branching ivy vine. Indeed, the wandering vine connects all five of the figures on this side of the vessel together in a single celebration of the god.

Figure. 12 a-c: Krater, Attic Bilingual; 515-510 BCE

I agree with Cohen's statement that the "measured pairing of Apollonan and Dionysian compositions...enhance the positive and negative effect of this vessel" (27). Apollo and Dionysus each have a very important place in the symposium. Apollo, as the god of music, symbolizes proper proportions and order in the symposium, while Dionysus, as the god of wine, highlights wild frenzy and freedom of action and expression. On this amphora, we see the contrast explicitly with Apollo holding his lyre on one side and Dionysus his kantharos on the other. Gods surround Apollo; satyrs and dancing maenads surround Dionysus. One represents order; the other, ecstasy. The red- and black-figure contrast only serves to emphasize these differences more.

The important messages of balance and moderation appear in many forms in the symposium, including through the images on opposite sides of vessels, which were meant to be read against one another. Contrasting themes convey the differences between who the ideal Athenian should and should not be. More specifically, I have discussed the contrasts between the exemplary aristocrat and immoderate beasts, women, and barbarians. These barbarians include both warlike ones outside of the realm of Athens and slaves within the Athenian homes. During the period from 525 to 500 BCE, artists began using the concept of bilingual to emphasize these differences. Thus, the images we have examined support similar messages of balance and moderation seen in the lyric poetry sung during the drinking party. Indeed, the two go hand-in-hand to teach these important virtues to the Athenian aristocrats of the late archaic period.

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Mentor Comments: Alexandra Pappas notes that Matt Naglak, like so many other authors in this issue, has been inspired by his studies in many fields. His work makes good use of his background in framing a unique contribution to Classical Studies.

Despite his relatively recent academic focus in Classical Studies – preceded by intensive training in math, physics, and computer science – Matthew Naglak's humanities-based research is original, exciting, and inspired, and was recognized as such in its early stages by a prestigious State Undergraduate Research Fellowship from the State of Arkansas. As his mentor, I can confirm the quality and originality of his work: he developed the topic on his own and, based on his extraordinarily wide-ranging research, formulated its organization. "Don't Rock the Krater: Balance and Moderation in the Ancient Greek Symposium"—of which this Inquiry publication is a part—is a sophisticated interdisciplinary project that sheds new light on material important for Classical art historians, philologists, and social historians. With an innovative perspective, Matt's work explores the ancient Greek ideology of living a balanced, moderate, and measured life. From the 7th-5th centuries BCE, poets, politicians and philosophers alike publicized the importance of the moderate path, and one particularly popular locus for this expression was the ancient Greek symposium, a male-only drinking party key for cementing aristocratic political ties and social bonds. Scholars have explored this social phenomenon, noting, for example, the great irony involved in a small group of politically powerful elites espousing moderation, the mean, and traveling "the middle path." Matt's research, in turn, asks whether there is evidence that this same ideology of moderation was expressed visually as well as poetically. He thus shifts the focus to the ancient Greek painted pottery that circulated alongside the poetry at the symposium, including storage containers for wine or water, cauldrons for mixing wine with water (the krater of his title), and the variety of cups for drinking mixed wine. He includes in his data set several unpublished vessels from the University of Arkansas Museum Collections. As Matt's research demonstrates, these objects, with their painted figural scenes in red and black, have much to add to our understanding of ancient Greek expressions of balance and moderation. Indeed, Matt shows that the sympotic audience regularly viewed scenes depicting physical feats of balance, which communicate the message rather literally. In this vein, too, Matt considers types of drinking cups that themselves, due to their odd shapes and curved bottoms, required careful balance by their users who could not put them down without a wine spill. Matt's project extends from the literal to the metaphorical, as he also considers images – either within the same scene or on opposite sides of the pot – that harmonize the extreme opposites embodied by the divinities Apollo and Dionysus. Although diametrically opposed in their powers, when read together visually, these gods create a moderate balance that was ideal within the symposium and, by extension, in public, political life. With the analysis of several additional visual modes of balance and moderation, Matt puts these expressions in their larger political context. He suggests that they are connected to the shift of political power from the elite aristocrats – that is, those attending symposia – to a broader base of citizens gaining increasing power as the fledgling democracy of the late 6th century BCE emerges. As should be clear, this project makes critical interventions in Classical Studies at a variety of levels, and is a stellar example of the kind of original undergraduate research being conducted at the University of Arkansas.

TRANSLATION RECOGNITION IN LEARNERS OF ARABIC

By Alia K. Biller

Department of Psychology

Faculty Mentor: William Levine

Department of Psychology

Abstract

The current study explored the role of phonology in the processing of Arabic words in native English speakers learning Arabic. Previous research demonstrates that three factors play a role in the mental processing of multiple languages: orthography, phonology, and semantics. Cognate studies have revealed that orthography is not the most important factor, but the roles of phonology and semantics are still indistinguishable from one another. The current study utilized phonologically-embedded English words within Arabic words at three different points in the word, beginning, middle, and end, to determine the role of phonology separate from that of semantics (e.g., تاريخ *, pronounced tareekh, and tar is a beginning overlap pair). Participants from the University of Arkansas Arabic language program completed a translation recognition task. They were shown an Arabic word, followed by an English word, and asked to identify whether the English word was the correct translation. It was predicted that participants would take longer to say "no" to false translations with phonological overlap than to false translations without phonological overlap and that less experienced learners would exhibit this effect to a higher degree than more experienced learners. While, as predicted, the reaction times for false translations with phonological overlap were substantially slower than reaction times for false translations without phonological overlap in beginning and middle overlap conditions, no significant differences were found. Arabic proficiency was found to be negatively correlated with amount of phonological interference. The results generally support the importance of phonology in the mental processing of multiple languages, which can be combined with other findings in language research to supplement language learning programs.*

Introduction

Learning a second language is almost a necessity in many fields today, including education, politics, and business. However, the processes of learning a second language vary, and their effectiveness depends on many different factors. For instance, approaches to language learning range from participating in a formal classroom setting to living abroad to using computer software. Second-language learning can also occur at any point in life, common points being early childhood, high school, and college. Furthermore, the relationship between the native language and the language being learned affects acquisition. For example, a native English speaker might be more adept at learning French than Mandarin Chinese due to the greater similarity between English and French. Any combination of approaches, ages, and languages may occur, along with many other factors, when learning a new language. Each combination specifically influences the rate of acquisition and retention and determines whether the learner ever truly acquires proficiency (Jared & Kroll, 2001). All of these factors are of great interest to researchers who wish to further uncover the process of learning another language.

The relationship between the native language and the language being learned is a factor of particular interest because the relationship itself has many components that can be explored. Some researchers investigate how similarities and differences in the grammar of two languages affect learning (Luk & Shirai, 2009). For example, does a native English speaker learn Arabic relatively slower than Indo-European languages because English has a sentence structure of subject-verb-object and Arabic has a sentence structure of verb-subject-object? Moreover, an extensive amount of research investigates how the relationship between multiple languages is represented in the mind (Drieghe & Van Heuven, 2002; Kerkhofs, Dijkstra, Chwilla, & De Bruijn, 2006). The main inquiries in this line of research are how the mind represents both languages and how these representations interact. In an examination of the literature, the exact nature of the mental representation of multiple languages often appears as a key to answering research inquiries. Within these mental representations, the associations among orthographic (i.e., the writing system of a language) representations, concepts, and phonological (i.e., the sounds that make up a language) representations emerge as playing an important role.

The current literature reflects an interest in the mental processing of multiple languages by articulating numerous theories. Kroll and Stewart (1994) proposed an influential theory called the "revised hierarchical model of lexical and conceptual representation" (RHM; see Figure 1), which is supported by much data. Its main tenet holds that processing and comprehending words in a second language (L2) is much more dependent on the first language (L1) than vice versa. This theory posits a strong link between L1 lexical items (i.e., words) and concepts. It also proposes that as an L2 is learned, the L2 lexical items are initially linked very strongly to the corresponding L1 word (e.g., *maison* in French to *house*) and very weakly to concepts (e.g., *maison* to all ideas about *house*). This results in L2 words being linked to concepts via L1 words during early stages of L2 learning. Therefore, an early L1 English learner of French seeing *maison* on a page would mentally (and unconsciously) progress from *maison* to *house* to all ideas about house instead of directly linking *maison* to all ideas about house. The RHM also posits that while the connection between L2 words and L1 words may be strong, the

reverse is much weaker. The same learner of French, upon seeing house, progresses very quickly and strongly to all ideas about *house* but very slowly and weakly to *maison*. In the later stages of L2 learning, the link between L2 words and concepts strengthens; thus, mediation via L1 words becomes less necessary over time. Many factors play a role in how all these links are established and how they develop.

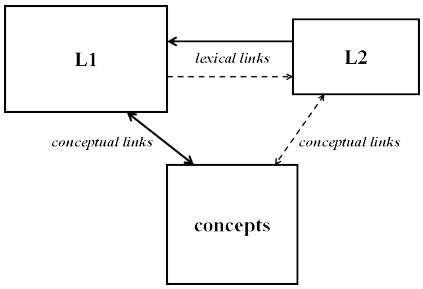

Figure 1. The revised hierarchical model (adapted from Kroll & Stewart, 1994).

The relative similarity between two languages can alter how they are mentally processed and, in turn, learned. Similarity can exist in many forms. Most important for the mental processing of words are phonological, orthographical, and semantic similarities (Gollan, Forster, & Frost, 1997). By investigating the roles of these similarities in the representation of multiple languages, researchers can gain insight into how words are processed, including whether processing one language activates another and how and under what conditions this happens.

Cognates are words in two languages that contain high degrees of orthographical, phonological, and semantic similarity in that they look and sound very similar and have almost the same meanings. False cognates (a.k.a. false friends or interlingual homographs and homophones) are words that have a high degree of orthographical and phonological similarity but no semantic similarity (Kim & Davis, 2003). *Bandage* in French and *bandage* in English, therefore, are cognates due to the fact that they have similar orthography, phonology, and the same meaning. *Avertissement* in French and *advertisement* in English are false cognates due to the fact that they have similar orthography and phonology but the French word means *warning* or *caution* and the English word is a type of publicity. Thus, cognates and false cognates allow the exploration of how similarities affect the mental processing of multiple languages.

In research literature, several facts about cognates have emerged. Cognates (*bandage-bandage*) are generally processed more quickly in the second language than words (matched on a number of variables such as frequency and length) that are non-cognate translations (*maison-house*) (Kim & Davis, 2003; Jared & Kroll, 2001; Gollan et al., 1997). Researchers often equate faster processing speed to significant priming effects. For instance, experimenters often utilize a lexical decision task (LDT) in which participants must decide whether a letter string on a computer screen is an actual word in the target language (e.g., *house* vs. *touse* if the target language is English). Frequently, participants complete a task before the LDT in which they somehow process words (e.g., read aloud a list of words). Thus, if participants initially read aloud the French words *bandage*, *maison*, and *bonjour*, they will likely most quickly decide that *bandage* is a word in English during the subsequent LTD. This result is called a priming effect because *bandage* in English was primed in the mental lexicon due to the presence of *bandage* in the first task. Priming effects are also seen in non-cognate translations (*maison-house*) but are not as strong (i.e., not as quickly identified during the LDT) (Gollan et al., 1997). Cognates and non-cognates provide an opportunity to test the three factors of orthography, phonology, and semantics in the mental processing of multiple languages in language learners and how they interact with one another.

Factors involved in the link between languages

There are many theories as to which of the three above-mentioned factors is most responsible for causing priming effects across languages. Gollan et al. (1997) argued that, because cognates have multiple shared lexical (i.e., orthographical, phonological, and semantic) representations, if the element of orthographic similarity were not present, priming effects would still occur. They conducted four studies with Hebrew-English cognates and non-cognate translation pairs which employed masked primes (i.e., a word was flashed quickly and then followed by random symbols) in one language and an LDT in the other language. Priming for both cognates and non-cognate translations was found, but only when the primes were in L1. Furthermore, priming for cognates was significantly stronger than priming for non-cognates in the same conditions. Gollan et al. argued that the stronger priming for cognates occurred because of their shared lexical representations. In other words, every time a cognate occurred in either language, the ability to recognize it in the other language increased. Therefore, under some conditions, orthographic overlap is not necessary for cognates to affect processing. In determining which lexical factors were most responsible for cognate priming and multiple-language processing in general, this study eliminated orthographic similarity, leaving phonological and semantic similarities as the causal factors.

Graduate and undergraduate students at Korean University participated in a study by Kim and Davis (2003) that examined the effect of task and similarity on priming. Cognates with semantic and phonetic overlap, non-cognate translations with only semantic overlap, false cognates with phonetic overlap (i.e., interlingual homophones), and a base group of words with no overlap across languages were utilized in different priming tasks, all of which were followed by an LDT. The results demonstrated significant priming following cognates and non-cognate translations. Thus, like the work of Gollan et al. (1997), this study eliminated orthographic similarity as necessary for priming, leaving phonological and semantic similarities as the causal factors and extending causality to different tasks and languages.

Bowers, Mimouni, and Arguin (2000) also posited that different lexical factors have different amounts of responsibility in the mental processing of multiple languages. However, they argued that orthographic similarity, rather than phonological or semantic similarity, is necessary to obtain cognate priming. Participants consisted of French-English bilinguals or Arabic-French bilinguals. The four conditions consisted of four different tasks, followed by an LDT. Notably, the cognate condition

involved reading cognates, and the cross-modal condition involved reading and speaking cognates. The French-English bilinguals demonstrated significantly greater cognate priming than cross-modal priming, while the Arabic-French bilinguals did not. However, the Arabic-French bilinguals did exhibit cognate priming. The authors argued that this result was due to the fact that cognate relations and their effects are bound to the orthographic system. However, these results only demonstrated that orthographic similarity may increase the strength of cognate priming and that lack of orthographic similarity does not eliminate cognate priming altogether.

Therefore, the links among L2 words, L1 words, and concepts in the RHM differ for cognates. Cognates compel the link that travels from L2 word to L1 word to concept (e.g., *bandage* to *bandage* to all ideas about *bandage*) to progress more rapidly than links for words that have lesser degrees of similarity (*maison-house* or *bonjour-house*). Both Kim and Davis (2003) and Gollan et al. (1997) revealed that of the three factors, orthography is not necessary to produce this quicker link. Yet, the roles of phonology and semantics are still indistinguishable from one another. It is unclear whether one factor facilitates the link more than the other.

The role of phonology in reading and production

Many tasks used in research on language processing involve visual presentation of words. However, even for silent reading, research demonstrates a considerable role of phonology in the reading process for monolinguals and bilinguals. For example, Ashby and Rayner (2004) tested the role of phonology, specifically syllables, in silent reading among monolinguals. Participants' eyes were tracked while they read, and each target word was preceded by a prime of either consonant-vowel (CV) or consonant-vowel-consonant (CVC) that matched or mismatched the target word on which reading time was measured. For example, the target word balcony had a CV match prime of ba and mismatch of tu, as well as a CVC match prime of bal and a mismatch of tug. The results revealed that matching CV or CVC to the target word produced shorter reading times. These findings support the theory that phonological representations, especially syllables, are utilized in silent reading.

Hoshino and Kroll (2008) studied the role of phonology in picture naming. Past research (Costa, Caramazza, & Sebastián-Gallés, 2000) illustrated that bilinguals name pictures more quickly when the picture is a cognate as compared to a non-cognate. The goal of Hoshino and Kroll's study was to determine whether the same effect exists when the scripts of the two languages differ. The participants were either Spanish-English bilinguals or Japanese-English bilinguals. In the critical trials, the participants were presented with pictures of an English-Spanish-Japanese cognate, an English-Spanish cognate, or an English-Japanese cognate and were told to say the name in English (the L2 for all participants) as quickly as possible; they were not alerted to the role of their L1 in the task. It was found that a similar pattern emerged for both groups of participants: faster naming when the picture was a cognate in their two languages. These results demonstrate the activation of phonology of the non-target language (L1), even when the orthographies differ.

Cross-language links in L2 development

Several studies have shown that similarities between words in two languages affect people in the early acquisition stages differently than those in the later acquisition stages. Most notably, Talamas, Kroll, and Dufour (1999) executed a study to specifically test multi-language processing at different levels of L2 proficiency. The authors cited the RHM, emphasizing that when an individual is beginning to learn a new language, there is a strong reliance on the L2-to-L1–to-concept link. However, words such as cognates seem to make the link progress more quickly. Talamas et al. proposed that with more learning, more-proficient L2 learners are better able to conceptually mediate L2, and mediation via L1 moves much more quickly or is eradicated completely. Because of this early reliance on lexical form (orthographical, phonological) to mediate access to concepts, the authors predicted that less-proficient bilinguals would be more sensitive to orthographical or phonological manipulations, while more-proficient bilinguals would be more sensitive to semantic manipulations.

To test these predictions, Talamas et al. (1999) created three groups of pairs of words for a translation-recognition task in English-Spanish: form-related pairs, semantically-related pairs, and unrelated pairs. In a translation-recognition task, each participant saw many word pairs and was asked to identify whether the second word in the pair was the correct translation of the first. When analyzing the false translation pairs, the authors found their predictions to be correct: the less-proficient participants were more influenced by form-related pairs, and the more-proficient participants were more influenced by semantically-related pairs. These findings suggest the occurrence of a shift in the process of second-language learning from a reliance on word form and sound (orthography and phonology) to a reliance on word meaning (semantics). Additionally, in their study, Gollan et al. (1997) found stronger priming effects for cognates in less-balanced bilinguals (i.e., those especially dominant in one language) in a post-hoc analysis. The cognates in Gollan et al.'s study were Hebrew-English and therefore only contained phonological and semantic overlap. Thus, Gollan et al. claimed that when less-balanced bilinguals process L2, they have a greater reliance on phonology than do more-balanced bilinguals.

Jared and Kroll (2001) performed a study that tested both the activation of phonological representations and the effects of level of proficiency on the mental processing of multiple languages. The participants were either French-English bilinguals or English-French bilinguals. The main goal of the study was to determine if French neighbors (i.e., words that share a word body with target word but have different pronunciations) slowed down the naming of English words. They created three groups of words. The first was the no-enemies group, meaning that the word bodies, the cluster of letters at the end of the word, were consistently pronounced in words across the English language and did not exist in French (e.g., *bump*, which has 'ump' as its ending, and which is pronounced consistently across all English words that contain it). The second group was the French-enemies group, which consisted of word bodies pronounced consistently in English and pronounced differently in French (e.g., bait [English] to *fait*, *lait* [French]). The third group was the English-enemies

group, in which the word bodies were inconsistent in English and nonexistent in French (e.g., *bead*, which has "enemies" such as *dead* and *head*). All participants named words presented to them in an English block, a French block, and then an English block again, after which they named pictures in French.

When analyzing the results, the authors also divided the participants into more- and less-proficient groups by accuracy in picture naming. Both proficiency groups showed more influence of French enemies only in the second block of English words, that is, only when previously exposed to French. Also, the less-proficient group showed more interference from the French-enemy pairs. Importantly, the study revealed that when the L1 was English, less-proficient bilinguals activated similar sounds in both languages to such an extent as to cause interference.

The current study

The current study builds upon the existing literature about the roles of phonological, orthographical, and semantic factors and levels of proficiency in the mental processing of multiple languages. The primary goal of the present study was to determine the extent to which phonology plays a role when a native-English speaker is reading Arabic. This was accomplished by using a translation-recognition task similar to that used by Talamas et al. (1999). While there already exists evidence that phonology plays a role in the processing of words by bilinguals across two languages with different scripts (i.e., alphabets), phonological effects have not been demonstrated in this type of translation task.

The translation recognition task allowed a test of the role of phonology without orthographic or semantic similarities in order to determine the degree of importance of phonology itself. The critical pairs were those that were incorrect translations and were also Arabic-English pairs in which the English word was embedded in the Arabic word (e.g., تاريخ [pronounced *tareekh*] – tar). Incorrect translation pairs were divided into three types based on where in the Arabic word the overlap occurred: a beginning, middle, or end (not rhyme) overlap (e.g., تاريخ [*tareekh*] – *tar* is a beginning overlap pair). Each embedded English word was used as its own control in a between-participants manner. For instance, if تاريخ – *tar* was seen by one participant; then the next saw tar paired with a different Arabic word (unrelated and length-matched to تاريخ).

The secondary goal was to test the effect of phonological similarity between groups with different levels of Arabic proficiency. This goal was accomplished by recruiting participants of varied experience and skill with Arabic.

It was predicted that the phonologically-related word pairs would interfere with making the translation-recognition decision more than phonologically-unrelated word pairs. Thus, phonologically-related pairs should have longer reaction times (RTs) than phonologically unrelated pairs. Although there is existing evidence that phonology plays a role in the processing of words by bilinguals across two languages with different scripts (i.e., alphabets) (Gollan et al., 1997; Kim & Davis, 2003), this has not been previously demonstrated in a translation task such as the one used in this study. Additionally, more experienced learners should have less interference than less experienced learners (c.f. Jared & Kroll, 2001, Talamas et al., 1999). Accordingly, experience should negatively correlate with measures of interference.

Method

Participants

The participants were 20 undergraduate students at the University of Arkansas enrolled in Arabic-language classes. Due to the structure of the Arabic program, each participant was in either the second, fourth, or sixth semester of study. An objective measure of the proficiency of each participant was gained from accuracy performance on a translation-recognition task which required recognition of correct and incorrect translations. Participants were recruited during a class meeting, at which students were informed of and offered the opportunity to participate in the study. All participants were monetarily compensated ($10) for their time.

Materials and Design

This study utilized a translation-recognition task. All Arabic words were found in book one of the Al-Kitaab Arabic textbook series (Brustad et al., 2004), the sole language source in the University of Arkansas' Arabic program. Due to the relative novice status of the participants, a frequency measure of written or spoken Arabic was not necessary or useful.

A list of 54 Arabic words was compiled as the experimental items of interest. Each of these Arabic words was paired with two English words: a correct translation (CT) and a false translation (FT). The FTs were of three types depending on where the English word's phonology overlapped in the Arabic word: beginning, middle, or end. For instance, a beginning overlap word was the tar in تاريخ (pronounced *tareekh*), a middle overlap word was the tab in مكتبة (*maktaba*), and an end overlap word was the loose in فلوس (*faloose)* (see the Appendix for a complete list of experimental items). CT reactions times were not of interest theoretically in this study. Additionally, the English word in each FT pair was paired with an Arabic word that was the same length as the original Arabic word to serve as a control.

A "family" of word-pairings thus contained three pairs: the CT, the FT, and the control. For example, one family began with the CT pair composed of the Arabic word تاريخ (*tareekh*) and its English translation of history. The FT in this family was تاريخ (*tareekh*) paired with tar. The related control was منطقة (*mintaqa*) paired with tar (see Table 1). Each participant only saw one of these three pairings. Therefore, the response time to tar in the FT pair was compared to the response time to tar in the control pair in a between-participants manner.

Table 1. Sample stimuli.

Overlap condition	Arabic word	Correct translation	False translation	Control
Beginning	تاريخ (tareekh)	history	tar	منطقة (mintaqa)
Middle	طاولة (teweela)	table	wheel	عايلة (aaila)
End	أخبار (ikhbaar)	news	bar	وظيفة (watheefa)

Note: Arabic words appeared in Arabic letters; the transliterations in parentheses are provided to illustrate the overlap in phonology between the Arabic and English words.

Two lists were created, each with 54 of the Arabic experimental words. One-third of the experimental words in each list were paired with the CT (*tareekh-history*), one-third were paired with the FT (*tareekh-tar*), and one-third were replaced by their control (mintaqa-tar). Of the 18 CTs in each list, one-third were beginning overlap, one-third were middle overlap, and one-third were end overlap. The same division occurred in the FTs and the controls. Each list was constructed so that if an Arabic word appeared with an FT on one list (e.g. *tareekh-tar*), then its control appeared on the other list (e.g. *mintaqa-tar*). Each participant only saw one list; that is, each participant saw tar only once.
In addition to the experimental trials, 54 filler trials were also seen by each participant. The purpose of the filler trials was two-fold. The first purpose was to equate the number of correct translations and incorrect translations seen by each participant. Thus, 36 filler trials were correct translations, and 18 filler trials were incorrect translations. Including both experimental and filler items, each participant saw 54 correct-translations pairs and 54 false-translations pairs. The second purpose was to ensure that some of the correct translations contained monosyllabic English words. This was necessary due to the fact that many of the FT English words were monosyllabic (e.g., tar). Therefore, the condition (CT, FT, control) and overlap (beginning, middle, end) were manipulated within participants, and the lists were manipulated between participants.

Procedures

Each participant was tested individually in a room with a computer using the DirectRT computer program. The labels "Y" and "N" were taped over the left and right arrow keys of the keyboard, respectively. During each trial, a (+) was seen in the middle of the screen until the spacebar was pressed to indicate readiness. The (+) was replaced by an Arabic word for 1500 ms, followed by a blank screen for 100 ms. An English word then appeared in the middle of the screen for 400 ms, after which a blank screen remained until the participant pressed the left arrow to indicate a correct translation or the right arrow to indicate an incorrect translation. The time from the appearance of the English word until the button press was recorded as the time required to decide whether the translation was correct. The (+) then reappeared.

Each participant first read instructions and completed two practice trials with an experimenter present. The participants were told to place the left hand on the spacebar and two right fingers on the left and right arrow keys. Upon concluding all trials, the order of which was randomized anew for each participant, the participants completed a language-history questionnaire (the results of which are not reported). The entire experiment lasted approximately 20 minutes. The participants were then debriefed and thanked.

Results

Data-screening

Twenty participants participated in the study. None of the data were excluded from analysis due to excessive errors on the translation-recognition task or noncompliance with instructions. For each participant, reaction times (RT) on correct translation-recognition trials that were classified as outliers according to Tukey's (1977) criterion were excluded from further analysis. This resulted in 6.0% of the RTs being excluded.

Correct Translations

For correct translations for experimental items, mean RTs and accuracy were calculated for each overlap type (beginning, middle, end). Beginning overlap showed a MRT = 1120, Macc = .83. Middle overlap showed a MRT = 1540, Macc = .89. End overlap showed a MRT = 1333, Macc = .89. Because these results are not of theoretical interest, they will not be discussed further.

False Translation and Controls

Mean RTs (see Figure 2) and accuracy (see Table 2) were calculated for FTs and their related controls for each overlap type (beginning, middle, end). For beginning and middle overlap items, reaction times for FTs were slower than those of the controls, as expected. For end overlap items, reaction times for FTs were very close to those of the controls.

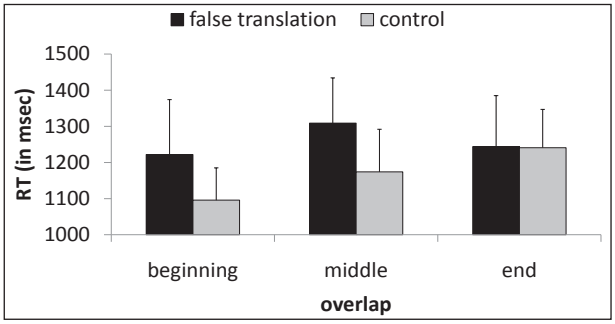

Figure 2. Mean reaction time for correct translation-recognition decisions as a function of condition (with standard error bars).

Table 2. Mean accuracies and reaction times on experimental trials as a function of condition.

	Accuracy		Reaction Time (in msec)	
Overlap condition	False Translation	Control	False Translation	Control
Beginning	.950 (.024)	.975 (.014)	1222 (151.7)	1095 (89.3)
Middle	.958 (.021)	.967 (.015)	1309 (124.7)	1174 (181.1)
End	.983 (.011)	.967 (.019)	1244 (141.1)	1241 (105.7)

Note: Standard errors/deviations are in parentheses

A 3 (overlap: beginning, middle, end) × 2 (condition: control, FT) repeated-measures ANOVA was conducted on RTs; an alpha level of .05 was adopted as the criterion for statistical significance. No significant main effect of condition was revealed ($F(1, 19) = 1.21$, $p = .29$), no significant main effect of overlap was revealed ($F(2, 38) = 1.56$, $p = .22$), and no significant interaction of overlap and condition was revealed ($F(2, 38) = 0.73$, $p = .49$). A 3 × 2 ANOVA was also conducted on accuracies, which were nearly uniform (all ≥ .95), with similar results. Therefore, neither condition nor overlap alone caused a significant difference in reaction time or accuracy. Additionally, no certain pairing of condition or overlap was significantly different for reaction time or accuracy.

Despite the ANOVA results, effect sizes were calculated for each condition. The mean reaction time, in milliseconds, for the FTs was slower than that of the controls for beginning overlap to an extent that the standardized effect size ($d = 0.26$) was at a

magnitude that is traditionally considered of medium size (Cohen, 1992). The mean reaction time for the FTs was also slower than that of the controls for middle overlap to such an extent that the standardized effect size (d = 0.34) was of medium size. The mean reaction time for FTs was very similar to that of the control for end overlap. Thus, only the effects seen in the beginning and middle overlap items were of medium size.

Proficiency

Proficiency was measured and correlated with interference measures. Performance (proportion correct) on filler trials was used as a measure of proficiency for each participant, ranging from .76 to .99 (M = .90, SD = .07). To examine the role of proficiency in the results, three interference scores were computed for each participant, one for each overlap condition. For instance, beginning interference for a participant was equal to that participant's mean beginning FT reaction time minus the mean beginning control reaction time. Proficiency scores were then correlated with the interference measures. Beginning and middle overlap correlations approached significance, while end overlap did not (beginning: r = -.40, p = .08; middle: r = -.39, p = .09; end: r = -.03, p = .92). The beginning- and middle-overlap correlations are both large in terms of effect size (Cohen, 1992). Therefore, the beginning and middle overlap conditions demonstrated a strong and nearly significant correlation, suggesting that the higher the proficiency, the lower the interference effect.

Discussion

This study was designed to examine whether phonological overlap across English and Arabic plays a role when native-English speakers read Arabic and whether less-experienced learners are more affected by phonological similarities than are more-experienced learners. Participants were recruited from University of Arkansas Arabic-language classes and were asked to complete a translation-recognition task. The false translations (FTs) of interest had an English word phonologically embedded at the beginning, middle, or end of the Arabic word (e.g., tareekh-tar). The reaction times of these FTs were compared to FTs in which no phonological overlap was present (e.g., mintaqa-tar).

Unlike cognates, the stimuli in this study contained Arabic-English word pairs with phonological similarities but without semantic similarities. Arabic and English were used in part because they share no orthographic similarities. It was predicted that pairs with phonological overlap would take longer to process than pairs without phonological overlap, resulting in longer reaction times. For beginning and middle overlap, FTs with phonological overlap produced the expected longer reaction times than FTs without phonological overlap. The differences were not significant, but the effect sizes for beginning and middle overlap were medium.

Earlier studies demonstrated that less-experienced learners are more affected by phonological similarities than are more-experienced learners (Gollan et al., 1997; Talamas et al., 1999). Therefore, it was predicted that the more-experienced learners would exhibit less interference, evidenced by a negative correlation between proficiency and interference. For each overlap type (beginning, middle, end), an interference measurement was calculated (FT reaction time – control reaction time) and was correlated with a measure of proficiency (proportion correct on filler trials). Beginning and middle overlap correlations approached significance at the .05 level. Thus, less-experienced learners appeared to be more affected by phonological overlap than were more-experienced learners.

The results of this study did not provide statistical confirmation of the predictions for the role of phonological overlap in processing Arabic words. There was nearly-significant evidence for predicted proficiency effects. The small sample size (n = 20), due to the difficulty in recruiting participants and time constraints, contributed to the lack of significant findings. Generally, the larger the sample size, the clearer the effects revealed in the data because irrelevant factors have less influence. Effects similar in magnitude to those reported above might be significant with a larger sample.

The end-overlap condition never mirrored the patterns shown in the beginning- and middle-overlap conditions. Various syllabic hypotheses posit that at least the first one or two syllables trigger lexical access, if not the first few sounds (e.g., Tagliapitra, Fanari, Collina, & Tabossi, 2009). The beginning overlap condition contained phonological overlap in the first syllable, and the middle overlap condition usually contained phonological overlap in the second syllable. According to the syllabic hypotheses, the first two syllables contain a great deal of information that plays an important role in (unconsciously) looking up words in one's mental dictionary (see also Ashby & Rayner, 2004). Thus, it is not surprising that the beginning- and middle-overlap conditions were more affected by phonological overlap than was the end-overlap condition. The pattern of data matches the predictions reasonably well, and beginning- and middle-overlap effects may be more evident with a larger sample size. Because the end overlap condition does not follow the pattern of results or predictions, it is probable that the end of a word plays little or no part in phonological processing. Therefore, further research would benefit by eliminating this condition.

Of the three factors that influence the links in the RHM (Kroll & Stewart, 1994), only phonology was tested in this study. Previous research nearly eliminated orthographic similarity as a necessary cause of cognate priming but demonstrated that it strengthens cognate priming (Bowers et al., 2000; Gollan et al., 1997; Jared & Kroll, 2001; Kim & Davis, 2003). Of the two remaining factors, phonological similarity affects less-experienced learners more than semantic similarity (Talamas et al., 1999). As less-experienced learners read relatively new words, they initially sound out the word, which, assuming they know the translation, activates the correct L1 translation and then finally the concept. In the process of sounding out the word, the English embedded word is also activated, or primed, which makes it harder to reject the FT (tar). Because more-experienced learners recognize words on sight instead of sounding them out, they are not as affected by phonological similarity. Of course, due to the nonsignificant outcomes in this study, this effect is only speculative, although there is evidence for this speculation in the findings of previous research (Talamas et al., 1999).

To further enhance this line of research, a condition

containing semantic overlap should be included and compared to the phonological-overlap condition in this study. The same basic experimental design is usable, but the critical FTs would contain semantic similarities instead of phonological (e.g. tareekh[history]–time). Proficiency correlation would be expected to demonstrate the opposite of those observed in the phonological condition. Semantic overlap is expected to interfere more with the processing of more-experienced learners than that of less-experienced learners (Talamas et al., 1999). The size of the effects overall in the two conditions should also be compared in order to determine if one condition exhibits stronger effects, which would indicate a more influential link in the mental processing of multiple languages.

Conducting other types of research concerning the degree of phonological and semantic similarity would also enhance these findings. A comparison of the effects of homophones, cognates, and non-cognates in Arabic-English bilinguals would further demonstrate which factors affect the processing of multiple languages. However, Arabic and English have a small percentage of homophones and cognates, very few of which are encountered by novice learners of Arabic. Moreover, many Arabic words that became an English word contain a definite article and noun. For example, الكحل is pronounced alkuhool, and means "the alcohol," whereas the English word alcohol is simply a bare noun without an article. Thus, this type of study would benefit from using participants from a truly bilingual population rather than relative novices in Arabic. Also, this type of study involving any two languages without orthographic overlap (e.g. English-Japanese) would likely produce more knowledge in the field of mental processing of multiple languages.

The current study built on previous findings and research concerning cognates but utilized words with partial phonological overlap instead of the full phonological and semantic overlap of cognates. The results revealed that phonological similarity may play an important role in the mental processing of multiple languages, but more research is necessary to determine its exact role. Often, language researchers work in tandem with coordinators of second language learning (SLA) and teaching English as a second language (TESOL) programs in order to implement new techniques. Phonology as a field is growing in importance within the SLA and TESOL communities (Jared & Kroll, 2001). By solving one piece of the puzzle at a time, researchers can discover the complicated process by which second languages are acquired.

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Mentor Comments: Dr. Levine's comments highlights Alia's use of her academic preparation in linguistics, psychology, and Arabic in developing this complex study related to second language acquisition.

The primary goal of Alia Biller's honors thesis research was to examine the representation and processing of Arabic words in native-English speakers who are learning Arabic. Although there is a huge amount of research in the cognitive psychology

of bilingualism, there is little research on bilinguals whose two languages are written in different scripts, and, to our knowledge, none on the pairing of English and Arabic. By examining learners relatively early in the acquisition of a second language, and across a range of proficiencies, Alia was able to find evidence of phonological overlap between the representation of Arabic and English words. This suggests that even in these two languages that do not share a script, reading Arabic words activates (irrelevant) English words that share sound information, especially among learners of Arabic with relatively-low proficiency. This research has theoretical implications for how a second language is mapped onto one's native language during acquisition, and potentially has practical implications for how second-language-acquisition programs might be fine-tuned to help students increase their proficiency more quickly. We will be presenting these findings at the 51st Annual Meeting of the Psychonomic Society in St. Louis in November, 2010. Alia's research represents the culmination of two-and-a-half years of collaboration between us, and is my laboratory's first foray into bilingualism research. This was made possible by her desire to prepare herself for a career in linguistics. Her interest in Arabic, language in general, and psychology, made this project a natural for us to work on together, and would not have happened if not for her sharp focus on her goal. It is very rewarding that Alia will be continuing her studies in the Master's in Applied Linguistics program at Boston University beginning in Fall, 2010, and that we will be able to continue our collaboration on this research.

Appendix: Experimental stimuli

Key to layout

Arabic Word, English Translation (English sound) (English Transliteration): classification and number of letters

Control: Arabic Word, English Translation (English Transliteration): classification and number of letters

Beginning Overlap Stimuli

أيضاً , Also (eye) (eyedan): adv4

فعلاً , Really(faalan): adv4

تاريخ, History (tar) (tareekh): noun5

منطقة , Area/region (mintaqa): noun5

صاحب , Friend (saw) (saahib): noun4

مساء , Evening (msaa): noun4

كتاب , Book (key) (ketaab): noun4

والد , Father (waalid): noun4

جيش , Army (Jay) (jaysh): noun3

جيش , Literature (adaab): noun3

سورة , Picture (sue) (suura): noun4

نهار , Daytime (nehaar): noun4

جريدة , Newspaper (jar) (jareeda): noun5

مدينة , City (madeena): noun5

ليلة , Night (lay) (layla): noun4

خالة , Maternal aunt(khaala): noun4

سياحة , Tourism (sea) (seeyaha): noun5

رسالة , Letter (resaala): noun5

بريد , Mail, post (bar) (bareed): noun4

غداء , Lunch (ghadaa): noun4

ورقة , Piece of paper (war) (waraqa): noun4

موظّف , Employee (muwathafa): noun4

حمّام , Bathroom (ham) (hammam):noun4

مجلّة , Magazine(majalla): noun4

Middle Overlap Stimuli

مترجم , Translator (gym) (mutarjim): noun5

موضوع , Subject (mowdoaa): noun5

قلواط , Table (wheel) (teweela): noun5

قلئاع , Extended family (aaila): noun5

مكتبة , Library (tab) (maktaba): noun5

مسلسل , T.V. series (musalsal): noun5

حقيقة , Actual, real (key) (hakekeya): adj5

متأخر , Late (mutakher): adj5

طفولة , Childhood (fool) (tafoola): noun5

بناية , Building (benaaya): noun5

تجارة , Trade (jar) (tejaara): noun5

مدرسة , School (madrasa): noun5

إقتصاد , Economics (tea) (iqtesaad): noun6

محاضرة , Lecture (muhadera): noun6

مباراة , Game (bar) (mubaara): noun6

مستقبل , Future (mustaqbal): noun6

علاقة , Relationship (lack) (3laaqa): noun5

أسبوع , Week (usbooa): noun5

مهندس , Engineer (hand) (muhandis): noun5

وزارة , Ministry (wezaara): noun5

مقالة , Article (call) (muqaala): noun5

جامعة , University (jaamiaa): noun5

منتصف , Middle (toss) (muntasof): adj5

مشغول , Busy (mushghool): adj5

End Overlap Stimuli

دائماً , Always (man) (da-imaan): adv6

بسرعة , Quickly (bisuraa): adv5

أخبار , News (bar) (ikhbaar): noun5

وظيفة , Position, job (watheefa): noun5

قصة , Story (saw) (qissa): noun3

لغة , Language (lugha): noun3

فلوس , Money (loose) (faloose): noun4

أسرة , Family (usra): noun4

علوم , Sciences (loom) (3loom): noun4

شارع , Street (shaaria): noun4

زميل , Classmate (meal) (zameel): noun4

صفحة , Page (safha): noun

أفراد , Individuals (rod) (aafrod): noun5

ساعة , Hour (saaa)

خريف , Autumn (reef) (khreef): noun4

صديق , Friend (sadeek): noun4

ازدحام , Over crowdedness (ham) (izdehaam): noun6

صيدلية , Pharmacy (sydalia): noun6

وحيد , Loneliness (heed) (waheed): noun4

درجة , Degree (daraja): noun4

أخلاق , Morals (lack) (ikhlaq): noun5

حديقة , Garden/yard(hadeeqa): noun5

مكان , Place (can) (makaan): noun4

حادث , Accident (haadith): noun4

FTC GUIDELINES ON ENDORSEMENTS AND ONLINE CONSUMER REVIEWS: BIASING CONSUMERS' INTENT TO BUY

By Alexander Cole
Department of Marketing and Logistics

Faculty Mentor: Molly Jensen
Department of Marketing and Logistics

Abstract

New FTC guidelines have been created to control improperly used endorsements with online consumer reviews. These guidelines state that bloggers and word-of-mouth marketers must disclose material connections if they are being endorsed in any way, and a paid endorsement is considered deceptive if it makes false or misleading claims. This study examines how this regulation may influence consumers' attitudes and behaviors regarding online reviews. The present research tests whether: a) previously documented bias effects of negative and positive reviews still exist under new guidelines; b) the minimal FTC requirements are sufficient to properly inform consumers; and c) a more standardized and elaborated statement would be more effective. A total of 276 participants were recruited to read a simulated online consumer review. Participants viewed one of three possible conditions (no endorsement statement, minimal FTC required statement, and modified FTC statement). Participants then rated their intent to buy the product, confidence in the purchase, and the influence of the review on the intent to buy and on confidence. There was a significantly lower intent to buy ($p < .01$) when the modified FTC statement was utilized, demonstrating the potential need for more standardized guidelines to be utilized in order to protect consumers. Implications of the study are discussed.

Introduction

Technology today has provided consumers with new tools to analyze products from home before even entering a store. These tools range from consumer reviews on websites to personal online blogs from other consumers. Internet information resources can keep individuals from making purchases as though blindfolded, but is this system flawed? The Federal Trade Commission (FTC) believes so. Fraudulent reviews do exist, biasing the inexperienced consumer into believing a product is better than it might be. This study analyzes the effects of new FTC guidelines with respect to online reviews and endorsements on consumers' intent to purchase a product.

Consumers not only want to have attribute-value information for a product or service but also desire recommendations from external information sources, such as word-of-mouth networks (Rosen & Olshavsky, 1984). This is especially true for uninvolved consumers who want an easier approach than searching for information (Mittal, 2004). Word-of-mouth networks have been shown to be effective in changing a consumer's attitude about a product or service (Katz & Lazarfeld, 1955; Benson, 1989). They have been judged to be both credible and relevant (Schiffman & Kanuk, 1997), further demonstrating their power in marketing. As a result, more involved consumers have assumed an increasingly active role in the advertising marketplace, slowly modifying the approach that marketers must take. One emerging role that consumers undertake is the posting of product reviews, in some cases becoming professional analysts of sorts.

With increasing Internet use, however, word-of-mouth reviews are combining with electronic media, thus allowing individuals to use mass communication through blogs, review sites, and even personal websites. To get his or her message across, a consumer may use websites such as Amazon, create personal blogs to discuss products, or even post video reviews on YouTube. The rise of online consumer reviews and electronic word-of-mouth mechanisms has been linked to increasing numbers of Internet sites allowing patron posts (Dellarocas, 2003). Bakos and Dellarocas (2002) discovered that these feedback and review mechanisms allowed smaller markets to link to a larger, "more-informed" market. Further, studies have demonstrated that online consumer reviews have successfully changed individuals' behavior, such as using online information to make offline decisions (Godes & Mayzlin, 2004). Online consumer reviews are beneficial to both vendors and consumers. Current literature illustrates the incentives for vendors to allow for online consumer reviews of products (Chevalier & Goolsbee, 2003). Online reviews provide a detailed indication of customers' perceived value of a product or service, which provides vendors feedback on how their product is portrayed in the market. For consumers, these reviews allow new customers who lack experience to have some guidance in the decision-making process. These influenced decisions can range from where to eat, what to buy, and even whom to trust in a trading or bartering situation (Guernsey, 2000; Dellarocas, 2003).

Dellarocas (2003) reviewed research that has been dedicated to the examination of online feedback mechanisms. A majority of studies have analyzed the implications of these feedback mechanisms in relation to online auctions, utilizing such websites as eBay. Since these auction feedback mechanisms provide a large-scale, online word-of-mouth tool for consumers to utilize in order to understand a product or service, they can be compared to the consumer reviews that are being analyzed for this study. Both auction feedback mechanisms and online reviews have been shown to help acquire and retain new customers at a lower cost (Mayzlin, 2003). Dellarocas (2003) also states that online feedback networks can help product development, quality control and supply chain quality assurance.

Clearly, there are benefits to marketing firms' taking advantage of online review mechanisms. It is also important

to note that reviews can also negatively influence consumers' willingness to purchase a product or service (Weinberger, Allen, & Dillon, 1981; Mizerski, 1982; Lee, Park, & Han, 2008). Further, consumer confidence in online reviews may be harmed because of the struggle to believe the "disembodied nature of online environments" (Dellarocas, 2003). Although more trustworthy and credible sources can lead to greater persuasiveness (Wilson & Sherrell, 1993), more recent research (Bickart & Schindler, 2001) suggests that this is not necessarily true for online communities. In an online context, consumers must trust the opinion of complete strangers. These strangers could be manipulating the situation to their advantage.

Even simple exposure to online sources, such as reviews or forums, can generate or increase interest in a product more so than basic marketing techniques (Bickart & Schindler, 2001). More recent research indicates a change in purchasing behavior when the product is given a negative consumer review (Lee, et al., 2008). As discussed in Lee, et al. (2008), one problem with online consumer reviews is the lack of a standard format, meaning that one review might be subjective and emotional, and another may contain factual reasons for the evaluation.

The anonymity of the online reviewer creates a situation that could potentially lead to misinformation, specifically in bolstering one company's reviews for an endorsement. For the purpose of this study, an endorsement is any advertising message that reflects the opinions of a party other than the sponsoring advertiser in exchange for product or monetary payment. For example, in early 2009, multiple Belkin employees were provided monetary payment for creating fake positive reviews for a product that had been negatively reviewed on Amazon.com. Belkin is specifically known for manufacturing and supplying audio, video and computer cables, power protection, wireless networking, iPod accessories, and desktop and mobility accessories. The fake reviewers artificially boosted Belkin's ratings on Amazon while belittling existing bad reviews in an attempt to increase sales. "Belkin business development representative Mark Bayard had used the Mechanical Turk service to ask users to write positive reviews of a Belkin product at a rate of 65 cents per review. The requests made it clear that writers need have no experience of, nor even own, the product in question" (cnet.com, 2009). Belkin President Mark Reynoso issued a letter of apology, and the reviews were immediately removed. "Belkin does not participate in, nor does it endorse, unethical practices like this. We know that people look to online user reviews for unbiased opinions from fellow users and instances like this challenge the implicit trust that is placed in this interaction," said Reynoso.

In response to Belkin's actions and dishonest reviews, the Federal Trade Commission (FTC) decided to enact new guidelines. In October of 2009, the FTC incorporated several changes to their Guides Concerning the Use of Endorsements and Testimonials in Advertising, which had not been updated since 1980 (FTC, 2009). These guides address endorsements by "…consumers, experts, organizations, and celebrities, as well as the disclosure of important connections between advertisers and endorsers" and reiterate that material connections, such as money or free products, must be disclosed. Specifically, the FTC provided examples that address endorsements produced by bloggers and word-of-mouth marketers who receive cash or in-kind payment to review a product. A paid endorsement is deceptive if it makes false or misleading claims. This would directly apply to the aforementioned Belkin scandal. The study described in this paper examines how these guidelines may influence consumers' attitudes and behaviors regarding online reviews.

In part, attribution theory is helpful in explaining consumer behavior. Early attribution theory suggests that an endorsement should be considered a strong incentive for the endorser to have positively biased behavior, meaning consumers should be more cautious about believing the endorser's emotions towards a product (Kelley, 1971). However there is contradictory research suggesting a phenomenon called the "correspondence bias" (Gilbert & Jones, 1986; Gilbert & Malone, 1995). When applied to endorsement literature, this theory indicates that even when situational factors such as endorsement fees are sufficient to explain the positive bias of endorsers, consumers inherit the positive behavior by observing the endorser performing the positive behavior. This implies that a consumer will like a product just because the endorser liked the product. Lafferty and Goldsmith (1999) provide evidence that an endorser's credibility has an effect on the advertisement and purchase intentions of consumers.

The source also plays an important role in affecting attitudes towards advertising effectiveness (Lutz, MacKenzie, & Belch, 1983). Much of the endorsement literature focuses on two major attribution models to further analyze the potential influence of endorsers and their credibility: the source credibility model (Hovland &Weiss, 1951) and the source attractiveness model (Friedman and Friedman, 1979; McGuire, 1985). The source credibility model is comprised of two distinct components, expertise and trustworthiness, which affect the believability and persuasiveness of the message (Hovland &Weiss, 1951). The source attractiveness model was introduced later to include attractiveness as another influence on endorsement effectiveness (Friedman and Friedman, 1979). Although this model focuses primarily on physical attributes, it also includes positive attitudes resulting from perceived similarity (McGuire, 1985). Since online reviewers are considered average consumers, this supplies a direct similarity that can cause the reviewer to be deemed more attractive.

It is important to note that previous FTC guidelines and endorsement research have been heavily influenced by the use of celebrity endorsements. Freiden (1984) demonstrated that the celebrity endorser scored higher on the attributions (expertise, trustworthiness, and attractiveness) than the CEO endorser, the expert endorser, and the typical consumer endorser. Silvera and Austad (2004) confirmed these results and created a predictable measurement for the effectiveness of such endorsements. However, in today's digital age, it is much harder to utilize a celebrity endorsement, and more consumers are using Internet sources for word-of-mouth information. A famous example of this online consumer information atmosphere is Wal-Mart's Elevenmoms, which began as a simple blog campaign for Wal-Mart products and thrifty shopping and has launched into a full

advertising campaign. However, these blogs normally feature individuals who are not experts or celebrities. Further, as shown by the Belkin example, individuals can also be rewarded with money or free product for online consumer reviews.

From one standpoint, the current FTC guidelines could be viewed as a device to warn consumers of false or biased reviews and thus protect consumers. However, the FTC guidelines do not provide a standardized statement and indicate that a simple sentence would suffice as long as the reviewer admits to compensation. Persuasion theory indicates that this might not be effective enough. Petty and Caccioppo's (1981, 1986) elaboration likelihood model (ELM) states that a successful change in attitude requires a certain amount of elaboration so that the person receiving the message thinks about what is being proposed. The ELM theory suggests that the stronger a peripheral cue, the more effect it will have on a target audience, meaning that a more elaborated statement will cause the reader to internalize the message. This has been replicated in other studies (Droge, 1989; MacKenzie and Spreng, 1992) with multiple variables being tested for the peripheral cue. It has also been successfully applied to sunscreen use (Detweiler, Bedell, Salovey, Pronin, & Rothman, 1999) and weight loss (Kreuter, Bull, Clark, & Oswald, 1999). With this in mind, one would think that the more standardized and elaborated an FTC-governed statement, the more effective it would be in informing the customer and influencing the intent to buy because it would be a stronger peripheral cue.

The following study examines three important issues: First, do the already proven positive and negative effect biases still exist with the new guidelines? Second, do the FTC guidelines have an effect on a consumer's intent to buy or the consumer's confidence in his or her choice when only the minimal requirements are met? And finally, if the current FTC guidelines do not actually influence the consumer, would a more standardized and elaborate statement help consumers realize the effects of endorsements? These questions are examined by applying the FTC's new endorsement guidelines and comparing non-regulated consumer reviews to newly regulated consumer reviews, both positive and negative. Further, a standardized and elaborated statement is used to determine if this has a greater effect than the minimal required statement. This will be referred to hereafter as the standardized statement. It is predicted that, although the current FTC guidelines will not show a significant influence on intent to buy, the more standardized and elaborated format will actually decrease intent to buy and confidence in both the positive and negative reviews.

Method

Participants

A total of 309 University of Arkansas students participated in the present study in exchange for bonus credit in a class. Each participant was randomly assigned to one of six different experimental conditions. Thirty-three participants were removed from the study for incorrectly answering a control question embedded within the questionnaire, leaving 276 participants (156 males, 119 females, 1 gender unidentified). The ages ranged from 19 to 48 years old, with a mean age of 22.2. Participants also provided information on their ethnicity (3 American Indian, 19 African American, 9 Asian, 229 Caucasian, 7 Hispanic, 2 Multiracial, 1 Pacific Islander, and 6 preferred not to answer).

Procedure

All participants were given the same scenario in which they were asked to imagine they were preparing for a trip to Europe and they were camera shopping, had narrowed their options to one fictitious brand, and were reading reviews before they made the final purchase (see Appendix, Section 1). Participants were then randomly assigned to one of six possible conditions – a positive consumer review, a positive consumer review with a current FTC-compliant statement, a positive review with a standardized endorsement statement, a negative consumer review, a negative consumer review with a current FTC-compliant statement, or a negative review with a standardized endorsement statement (see Appendix, Section 2, for the positive and negative reviews). In order to create realistic statements, many online camera reviews were analyzed, and general positive and negative statements were compiled.

For the conditions involving minimum FTC compliance, the statement "I was given this camera by Kallos to review" was added to the beginning of either the positive or negative review. For conditions containing the standardized statement, the statement was added to the beginning of both the positive and the negative review: "The Federal Trade Commission signifies the following review as an endorsement, meaning this individual was given the following product or paid to write the following review. Due to this endorsement, the following review might not signify standard expectations of using the product." In order to create an appropriate standardized statement, governmental warnings were analyzed, and a general statement was compiled after pilot testing.

After reading the consumer review, participants answered questions about how likely they were to buy the camera, how confident they felt about their choice, how much the review influenced their decision, and how much the review influenced their confidence level. Next, participants were given a set of items which asked them to rate how often and why they used consumer reviews in various forms (see Appendix, Section 3, for key survey items).

Results

Analysis of variance (ANOVA) procedures were used to examine bias effects as well as the impact of new minimal FTC guidelines and a standardized and elaborated statement on participant intent to buy and review influence..

Bias Type

Table 1 contains the means for each group (extremely low = 1, extremely high = 5). There was a main effect for review bias. Respondents who read positive reviews expressed greater intention to buy than those who read negative reviews ($F(1, 275) = 400.92$, $p < .01$), greater confidence in their decision than those who read negative reviews ($F(1, 275) = 60.35$, $p < .01$), and lower subjective influence of the review on their intent to buy than those who read negative reviews ($F(1, 275) = 10.53$, $p < .01$). Neither positive nor negative reviews influenced consumer's subjective ratings of the review's influence on his or her confidence level.

Table 1. Mean scores based on bias type.

Dependent Variable	Bias Type	Mean	Std. Error
Intent to Buy	Neg	1.955_a	0.072
	Pos	3.908_b	0.066
Confidence	Neg	3.021_a	0.087
	Pos	3.931_b	0.079
Influence on Intent To Buy	Neg	3.957_a	0.08
	Pos	3.604_b	0.073
Influence on Confidence	Neg	3.696_a	0.083
	Pos	3.637_a	0.075

*Significance determined by differing subscripts

FTC disclaimer

Table 2 contains the means for each group (extremely low = 1, extremely high = 5). Minimally FTC-compliant reviews did not have a significant effect on intent to buy or confidence level over the non-compliant reviews. However, the modified FTC reviews containing the standardized and elaborated statement demonstrated main effects. Respondents who read the modified FTC statement expressed a lower intention to buy ($F(2, 274) = 5.56$, $p < .01$ and lower subjective influence of the review on their intent to buy ($F(2, 274) = 6.14$, $p < .01$). Respondents who read the standardized FTC statement also expressed lower subjective influence of the review on their confidence level ($F(2, 274) = 3.47$, $p <= .03$). There was no significant effect on the actual measured confidence expressed.

Table 2. Mean scores based on FTC type of disclaimer.

Dependent Variable	FTC Type	Mean	Std. Error
Intent to Buy	Non FTC	3.095_a	0.078
	Minimal FTC	3.006_a	0.078
	Modified FTC	2.692_b	0.096
Confidence	Non FTC	3.548_a	0.093
	Minimal FTC	3.503_a	0.094
	Modified FTC	3.378_b	0.116
Influence on Intent To Buy	Non FTC	3.867_a	0.086
	Minimal FTC	3.973_a	0.087
	Modified FTC	3.500_a	0.107
Influence on Confidence	Non FTC	3.796_a	0.089
	Minimal FTC	3.76_a	0.09
	Modified FTC	3.444_b	0.111

*Significance determined by differing subscripts

Bias type X FTC disclaimer

As stated above, positive reviews were associated with higher purchase intentions, while negative reviews were associated with lower purchase intentions, and there was a main effect of the modified FTC statement on intent. There was also an interaction ($p<.10$) between the modified FTC and the positive review bias with regards to intent to buy and influence on intent to buy. Participants who viewed the positive review with the modified FTC had a significantly lower intent to buy ($F(2, 274) = 2.479$, $p < .10$) than the other groups (see Table 3). Additionally, participants who viewed the positive review with the modified FTC believed that the review had less influence on their intent to buy ($F(2, 274) = 2.494$, $p < .10$) than the other groups (see Table 4).

Table 3. Intent to buy

	Positive	Negative
Non FTC	4.11_a	2.08
Minimal FTC	4.1_a	1.91
Modified FTC	3.51_b	1.87

*Significance determined by differing subscripts

Table 4. Influence on Intent to buy

	Positive	Negative
Non FTC	3.84_a	3.9
Minimal FTC	3.81_a	4.13
Modified FTC	3.16_b	3.84

*Significance determined by differing subscripts

Discussion

The above results allow certain conclusions. First, it is important to note that the previous literature involving online consumer reviews was validated. Consumers that were exposed to a positive review were more willing to buy the reviewed product than were those exposed to a negative review. This suggests that, when used, online reviews are generally trusted, providing empirical support for how Belkin was able to easily manipulate consumers with false reviews. The FTC noticed this as well and implemented new guidelines to control this problem. However, as this study suggests, the current FTC guidelines might not be sufficient due to the minimal information requirements. This could be due to many factors, but the most important is the lack of a true peripheral cue. The singular sentence required under the new FTC guidelines might not be sufficient to grab the consumer's attention.

Within the study, more elaborate guidelines were proposed and tested in order to establish a standardized statement of endorsement. As demonstrated in previous elaboration likelihood model literature, this statement would indicate the possibility of dishonesty and cause consumers to internalize the importance of endorsed products. The results support the premise that a more elaborated statement of endorsement would be helpful to consumers. Participants that viewed the positive review with the modified FTC statement were less likely to purchase that product. The source credibility model could explain this result, since now the reviewer would be perceived to be less trustworthy given that they had something to gain with a positive review. The negative information provided by the modified FTC statement could be

viewed as a more valid review, since a paid individual would not be biased to speak negatively. When using the modified FTC statement, companies would have to determine if online reviews were beneficial, and this statement could deter if not completely stop dishonest practices such as those performed by Belkin.

The current research is a first step in a complex research agenda and should be used as a catalyst for future research endeavors. One important limitation in this study is the lack of a true control group. Future research should include a group either shown no review or one exposed only to general product information. Further, the research sample contained only university students; thus it might not be representative of the entire population of Internet users. Also, providing the endorsement statement at the beginning of the review could have produced additional bias; other statement placements should be tested. Future research could also employ different standardized statements as peripheral cues to educate and protect the consumer. Certain questions used in this study might have been confusing for participants, such as the influence questions. The questions could also be modified to include trust measurements in order to determine how much the participant trusts the reviewer. It would be important to perform a manipulation check to ensure that the two FTC reviews are viewed as endorsed products. Future research might analyze product categories in addition to electronics (e.g., home supplies, cars, clothing). Research could utilize differing price points to determine if the price would control the endorsement's influence.

The Internet is a superb resource that allows individuals to shop for products and review other consumers' experiences with a specific product. However, as the Belkin situation demonstrated, online reviews and consumer trust can be abused and used to a company's advantage. The Federal Trade Commission is providing guidance in the correct direction, but as this research suggests, current formats might not be sufficient to properly protect the consumer. Perhaps endorsement statements need to be standardized to protect the interest of the consumer, but standardization could also lead to a change in industry practice, causing companies to analyze the costs and benefits of utilizing online reviews. With the current trend of consumer behaviors' becoming more detached from personal face-to-face interaction and relying more on web interaction, the current research in this area could be a critical asset to both the consumer and companies.

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Mentor Comments: Professor Molly Jensen highlights a recurring theme in this journal issue – the influence of multiple disciplines on the research of our U of A undergraduate students.

Alex's research interest stemmed from his work environment and his dual majors in Marketing and Psychology. It was in our weekly meeting that we first discussed the Federal Trade Commission's (FTC) institution of guidelines in the area of online endorsements. According to the FTC, the intent of the guidelines was to protect the consumer. Topics involving public policy research are common in Business, but with the timeliness of the set of FTC guidelines there is no other research to date concerning this topic. With the advent of Web 2.0 and the proliferation of online shopping experiences consumers are more intimately involved in the review process. The access and the ease of giving reviews have exponentially grown. In addition, those using the web expect to see reviews and report making purchase decisions based on these reviews. This research explores the effects of these guidelines and evaluates their consequences intended or otherwise. Research does not occur in a vacuum. Research does occur in a collaborative environment and Alex has had full responsibility for his project in a collaborative environment. He has taken ownership in each step and has shown great tenacity during the process. Alex demonstrates a passion for research. Alex earned the distinction of Best Honors Thesis in the Walton College of Business for 2010. His thesis has already been submitted and accepted to a national marketing conference for presentation in November of this year. Alex is receiving honors in two colleges and intends to continue on to graduate school. He has committed to continuing to work with me and another colleague, Steve Kopp PhD on this project after he graduates and moves. Alex is exactly the kind of student we should be rewarding, encouraging and supporting through publications such as the Inquiry. It has been my pleasure and honor to be his thesis advisor.

Appendix: Survey Items

Section 1: Scenario Statement

"Please imagine yourself in this role: You have decided you really want to buy a new camera for your upcoming trip to Europe that you are going on soon. Your old camera quit working a few weeks ago. You have been debating about many different cameras, but have finally narrowed it down to the Kallos Quickshot Pro because it seemed to be very competitive for the price. Before you decide to buy it, you are just reading a quick review to make sure that it meets all your needs and wants."

Section 2: Reviews

Positive

"I was in Mexico and my other camera just broke on me the last 2 days I was there. I was very upset about it because I paid lots for it when it first came out. Got back to the states and got this one and I am HAPPY beyond words. There are no focus issues what so ever even on close up items and video works wonderful on it. There is not a thing I would change about this camera. Night time photos are great. The panoramic setting is really fun. It's easy to use for ANYONE!!!! The time between photos is really fast & makes it hard to miss a shot. I am very pleased with this camera. I'd say GET IT if you are looking!!!!"

Negative

"The viewer is very blurry when trying to focus in on my kids, which is unexpected for the price I paid. Everything seems to have a red tint to it in my pictures too. I cannot find the red light that tells you when the battery is charged so I had to buy a separate charger, which cost me even more. I am a hardcore Kallos user and have owned 5 so far but this one is disappointing. The memory card is easy to put in and take out, but the slot that opens to expose the battery and memory card is flimsy. I don't know how long this camera will hold together."

Section 3: Key Survey Items

Please use this scale to answer the following questions

	Extremely Low	Low	Neither High nor Low	High	Extremely High
How likely are you to buy the Kallos Quickshot Pro for your trip?					
How confident do you feel about your choice?					
How much influence did the review have on your decision?					
How much influence did the review have on your confidence level?					

I KNOW WHAT YOU DID LAST SUMMER: THE BALLOT INITIATIVE AND VOTER TURNOUT

By Shayne Henry

Department of Political Science

Faculty Mentor: Janine Parry

Department of Political Science

Abstract

"Know Thy Neighbor," a public interest group established in 2005, has grabbed headlines in recent years for making public (or threatening to make public) the names of hundreds of thousands of registered voters who signed petitions qualifying anti-gay rights measures for state general election ballots in Massachusetts, Florida, Arkansas, Oregon, and Washington. These names, together with the mailing addresses, birthdates, and dates of signature for each signer, have long been public information in most states, but never before have they been put into a format (i.e., searchable, online databases) making them easy to access and analyze. In this pilot project, I perform multivariate analysis on a random sample of 500 registered Arkansas voters to determine the relative role of petition signing (versus vote history and age) in spurring voter turnout. This unique dataset allows an analysis, at the level of the individual voter, of the effectiveness of a relatively new tactic in American politics: using ballot measures to stimulate turnout for up-ticket candidate races. In the current study, while there was a correlation between petition signing and voter turnout, at the level of multivariate analysis, petition signing did not appear to be associated with voter turnout. However, individuals who signed petitions tended to have strong voting histories and were more likely than non-signers to cast ballots in the 2008 general election. The results of this research add to the already robust literature analyzing voter turnout in US political elections.

Introduction

Research on voter turnout has traditionally focused on factors such as sex, age, race, education, economic classification, and other demographic traits (Verba and Nie 1972; Leighley and Nagler 1992; Rosenstone and Hansen 1993). The results of these studies demonstrate that higher levels of education and affluence correlate with increased levels of voter turnout and political interest. Further, older voters go to the voting booth on a more consistent basis than younger voters. Other research has looked at the effect of interaction with political institutions: voter mobilization strategies, party contact and identification, and previous voting history (Powell 1986; Blais and Carty 1990). Voters who have long histories of voting, strong connections to political institutions such as political parties or special interest groups, and high levels of contact in the months leading up to the election appear to vote in higher numbers. Some research has even looked at the role of initiatives in voter turnout, identifying which groups of voters are most influenced by the presence of a ballot initiative on a midterm or presidential ballot (Donovan, Tolbert, and Smith 2009). Little research, however, has analyzed the effect of initiatives at the individual level.

Literature Review

Voter turnout in the United States is low. In fact, U.S. voter turnout, which is around 60% for presidential elections and 40% for midterm elections, is among the lowest in the industrialized world (Powell 1986). States have tried to address this problem with innovative voting techniques such as mail-in ballots, same-day voting registration, and Internet voting programs. While some of these tactics, such as mail-in ballots in Oregon, appear to be successful, many of them have had marginal effects or simply have not been implemented at all because of a fear of increased voter fraud (Southwell and Burchett 1997). As a result of low turnout rates, a considerable amount of research has been done to analyze voter mobilization and participation in the United States.

Green and Gerber (2005) point out that the study of voter turnout has progressed greatly in the past several decades. Early research measured the dependent variable (turnout itself) through voter surveys (Rosenstone and Hansen 1993). These surveys were often inaccurate, with many respondents being less than truthful about their voting habits. The independent variables, usually registration laws and campaign mobilization activities, were incorrectly considered exogenous. Modern research has moved away from voter surveys and has begun using actual voting records to measure the dependent variable (voter turnout). In an effort to more accurately determine causal relationships, researchers have started recognizing that registration laws and campaign mobilization tactics are often spurious and unrelated to the level of turnout. An example of this would be situations in which registration laws are relaxed in areas with already high turnout. Thus, information on voting behavior has been added to the already large body of research on factors influencing voter turnout.

Voter Turnout and Mobilization

The likelihood of voters to actually cast ballots often relies principally on two overarching factors: socioeconomic conditions (and often intrinsically linked to this, demographics) and the presence of traditional campaign efforts targeting voter mobilization. Indeed, mobilization campaigns often target various voters differently based upon socioeconomic status.

Socioeconomic status and race are often interlinked, especially when it comes to voting trends. In fact, race has long been an established factor in voter turnout. While the voting gap between black and white voters in the United States had nearly evaporated

in presidential elections by the end of the 20th century, the gap remains in other election cycles (Gaither and Newburger 2000).

Southwell and Pirch (2003) examined the differences in attitudes between black and white voters in the United States. Their study revealed that black voters respond to increased political cynicism and distrust with higher levels of voter turnout, while the opposite happens with white voters. Further, white voters are more highly affected by sentiments of decreased efficacy than are black voters. The results showed clear differences in voting behaviors along racial lines. Race as a factor in voting behavior is largely structural. One study found that precinct quality, including poll station accessibility and quantity, in low-income and minority communities was on average lower than precinct quality in more affluent and Caucasian communities. Further, the voting stations in minority communities suffered from lower visibility and other characteristics that generally coincide with lower levels of voter turnout (Barreto, Marks, and Woods 2004).

Along with race, a voter's level of education is one of the strongest characteristics contributing to voter participation.[1] A large body of research identifies education as a factor in voter turnout (Nie, Junn, and Sehlik-Barry 1996; Wolfinger and Rosenstone 1980). Individuals with higher levels of education tend to vote in larger numbers and self-identify as more interested in political issues than individuals with lower levels of education.[2]

Robert A. Jackson (1996) takes a much different approach to the issue of demographic variables, dealing with voter demographics and turnout separately. Jackson separates voter engagement into two stages: the initial obstacle of registration and the subsequent step of actual voting. According to Jackson, individual voter characteristics have a greater effect on the registration of voters, while campaign activity has more bearing on actually bringing them to the polls.

Lack of party identification, or at least a weak affiliation with a political party, has been shown to correlate with a lower propensity to vote (Campbell 1966). As voters increasingly disassociate with established political parties, or at least the two predominant Democrat and Republican American political parties, levels of voter disillusionment increase and voter turnout decreases (Patterson 2002; Belanger 2004). Candidates and interest groups are left trying to devise methods to reengage independent and dissatisfied voters. Studies suggest that independents respond positively, by turning out in higher numbers, to the increased presence of ballot initiatives during midterm and general elections. Further, independents are more engaged by the presence of ballot initiatives than are voters with strong party identification (Magleby 1984; Donovan, Tolbert, and Smith 2009).

Lassen (2005) found that increased information resulted in higher voter turnout and demonstrated that voter information campaigns, especially at the district level, resulted in a higher likelihood of voter participation. For this reason, many states mail out flyers or pamphlets to registered voters before upcoming elections in order to inform them of issues that will appear on the ballot and to remind them to vote. In Denmark, where Lassen's study took place, the municipalities mail voter papers to every citizen before an election. The mailing serves as both a reminder to vote and as a form of authenticity that voters must bring to the polling sites.

Voter mobilization and contact have also been identified as factors in voter turnout. A study by Goldstein and Ridout (2002) reveals the relationship between voter contact and turnout but questions the trend of decreasing voter turnout over the past several decades. In this study, it was established that mobilization had not decreased over the years and voter contact targets had actually become more specific. If voter mobilization became less effective, it may have been because mobilization tactics tended to increasingly target those voters who were most likely to vote already, such as strong party supporters and activists (Huckfeldt and Sprague 1992). The problem with mobilization, Goldstein claims, is not the volume of contact but the individuals being contacted. While political parties often reach out only to registered voters from their party because of a fear of mobilizing individuals from the opposing party, it would appear that a more effective technique would be to identify and target independents and undecided voters, as research shows that these are the individuals most affected by voter contact and mobilization strategies (Niven 2004; Parry, et al. 2008).

Another explanation for decreasing turnout despite an increasing volume of voter contact may be that mobilization tactics are becoming less personal in order to increase the number of voters that are contacted. For example, campaigns may use more robocalls and mailers and fewer door-to-door canvassing efforts or attempts to engage individuals in public places. According to Green, Gerber, and Nickerson (2003), mounting evidence suggests that "the effectiveness of voter mobilization efforts depends on [a] personal touch."

Voter Turnout and Ballot Measures

Existing research shows a clear correlation between the presence of a ballot measure and higher voter turnout during elections (Smith 2001; Lacey 2005). The ballot initiative has a long history

[1]It is important to note that levels of education often correlate with income and affluence, so these demographic characteristics have similar correlative effects with voter participation. This is not always the case, however. Some research has attempted to study the voting habits of cross-sectional voter subsets, such as highly educated low-income voters or high-income voters that have little education (Jackson 1993). Various factors, such as high-stimulus congressional races or amounts of funding may affect voters differently along more complex lines than just "rich/poor" and "educated/uneducated."

[2]Tenn (2005) draws upon a relative education model created by Nie, Junn, and Sehlik-Barry (1996) in order to explain why an increase in the absolute level of national education from decade to decade has not resulted in increases in absolute voter turnout. This study looks at education in relative terms, voter against voter, in order to reassert the existing positive correlation between levels of education and voter turnout.

but has consistently been an effective tool in mobilizing voters.[3] This fact may be due to several reasons, such as higher issue saliency, increased campaign spending, and the so-called "educative" effect.

The ballot initiative is a Progressive Era tool of direct democracy. The Progressive movement was marked by an attempt to check the authority of political institutions by putting power in the hands of the people (Price 1975). Donovan and Bowler (1998) conclude that initiatives change the policy-making landscape by providing a conduit through which groups can influence policy making in an avenue other than the legislature.[4] Further, early reformers recognized that the result of increased direct democracy was a more engaged citizenry (Key and Crouch 1939). A more engaged citizenry, the Progressives argued, was one that would hold political institutions more accountable. In fact, the very threat of an initiative might often be enough to move a legislature to action (Gerber 1998).

States that use the initiative process with more regularity appear to have higher voter turnout than states that do not often use the process of direct democracy or do not have initiatives available to voters (Smith 2001; Lacey 2005). The reason for this effect is that the presence of a ballot initiative results in higher campaign spending and more media coverage.[5] Increased campaign spending and media coverage result in greater visibility for upcoming elections, as well as energized political bases. By definition, initiatives are usually voter initiated and thus typically include issues that are closer to the interest [6] of the voters. This increase in policy salience, because of increased visibility and public interest, results in increased voter participation (Mendelsohn and Cutler 2000; Smith 2001; Bowler and Donovan 2002; Smith 2002; Matsusaka 2004).

Further, it is believed that direct democracy results in an "educative effect," in which people learn about and become more highly involved in the political process (Smith and Tolbert 2004). The goal of the Progressive Era reformers who created the initiative in the early 20th century was to bring political control closer to the people.[7] Recent research, however, has shown that some effects of direct democracy, specifically increased turnout due to voter contact, do not continue for long periods of time, as voters who are engaged in the direct democratic process of a single initiative or a single election do not appear to continue at the same levels of engagement in future elections (Yalch 1976). This finding is in contrast with those of other studies that show pre-election contact, such as phone surveys or interviews, do have a continuing effect, perhaps due to increased levels of voter self-awareness (Kraut and McConahay 1973). It would appear, then, that there is no consensus among researchers regarding whether the educative effect of initiatives lingers beyond a single election or simply has a short-term discrete effect on voter turnout.

Both major American political parties, Democrat and Republican, have relied on the assumption that ballot initiatives may have an effect on partisan voter turnout or candidate perception, which is one reason Democrats have pushed for minimum wage initiatives and Republicans have supported the inclusion of anti-gay marriage propositions on ballots. Research seems to support this assumption. For example, the presence of state marriage initiatives in the 2004 election coincided with higher levels of saliency for marriage as an issue in analyzing presidential candidates (Nicholson 2005; Donovan, Tolbert, and Smith 2009). Gay marriage bans have been attributed to the large evangelical turnout in the

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[3] Some political scientists hold a more critical view of direct democracy and the initiative process. Many, including Matsusaka (2004), feel that many ballot measures are decided by voters who simply are not prepared to make informed decisions at the ballot box. Bowler and Donovan (2004), although not necessarily opponents of the initiative, point out that voter knowledge regarding initiative issues often comes from limited sources, namely television media and campaign commercials. This lack of knowledge leaves voters open to deception and manipulation on the part of interest groups. Lack of voter competence, critics argue, raises concerns about the integrity of the direct legislation process (Magleby 1984).

[4] Indeed, more than just the policy landscape may be changed by the presence of an initiative on a ballot. Research suggests that the use of the initiative by states results in an ideological shift in policy from policies made by states without the initiative. Specifically, initiative states tend to enact more conservative and socially restrictive policies than states without the initiative, especially on the issue of abortion (Gerber 1999; Bowler and Donovan 2004).

[5] Money may be a more important part of this equation than previously realized. Studies show that there is a strong shift in influence towards wealthy individuals and groups who can raise the most campaign funds for their side of the initiative. David Broder (2000) asserts that the initiative process at the state level has been an experience of wealthy individuals and interest groups manipulating the process for their own purposes. It is interesting to note, though, that while wealthy individuals or interest groups are in the position to best enact policy by creating an initiative and heavily funding it, money actually has its largest effect when spent against an initiative (Gerber 1999).

[6] Initiatives also tend to result in policies that are antagonistic towards the minority (Gamble 1997; Schrag 1998).

[7] Contrary to the goal of progressivism, initiatives provide a rich opportunity for interest groups to influence the policy making process, a concept known as the group theory of government. An organized minority can gain favor and political power over the unorganized majority by using tools such as the initiative (Truman 1951; Posner 1974). Such actions might hinder majority outcomes in democracies.

2004 election that pushed George W. Bush over the edge in the presidential race.[8] Because of empirical examples such as this, politicians hoping for higher turnout among supporters often connect their campaign platforms to state ballot initiatives in order to engage the citizenry (Chavez 1998; Kousser and McCubbins 2005).

Ultimately, research suggests that the presence of an initiative does result in higher voter turnout.[9] In fact, according to a study by Tolbert, Grummel, and Smith (2001), during the 1990s the turnout rates in initiative states were 7% to 9% higher than the turnout rates in non-initiative states during midterm elections and 3% to 4.5% higher during presidential elections.

Gay and Lesbian Adoption in Arkansas

The issue of gay and lesbian adoption and foster care has had a storied history in Arkansas over the past decade. Conservatives in the state have been trying for years to address two related issues, gay adoption and gay foster parenting. From the late 1990s to 2008, there was a bureaucratic, judicial, and political struggle to remove homosexual individuals from these areas of parenting. In 1999, the Arkansas Child Welfare Agency Review Board decided to bar homosexuals from becoming foster parents in the State of Arkansas.[10] Four homosexual Arkansans challenged the constitutionality of the policy in a lawsuit against the Review Board, arguing that it violated their rights to privacy and equal protection guaranteed by the Arkansas and US constitutions (Shurley 2002). The case was caught for years in pretrial procedures before eventually being heard by the Arkansas Supreme Court, which, seven years later, unanimously struck down the anti-gay foster care policy. According to Lambda Legal, the Court found that "the evidence overwhelmingly showed that there was no rational relationship between [the blanket exclusion of gay and lesbian foster parents] and the health, safety and welfare of foster children."

In 2005, before the Arkansas Supreme Court's ruling on the Review Board's ban on homosexual foster parents, the Department of Human Services also adopted a ban on putting children in foster homes with a homosexual adult. The Department of Human Services later lifted this administrative ban in 2008, shortly before gay adoption and foster care were outlawed through a ballot initiative.

On the legislative front, conservatives attempted in 2001 to pass legislation in the Arkansas General Assembly banning gay adoption in the state. House Bill 1026 narrowly failed to make it out of committee, with nine votes in favor of recommending the bill and 10 against it (Rowett 2001). Proponents cited a 1989 psychological study that claimed children in gay households were more likely to engage in incest with their parents and become gay themselves. Opponents pointed out that the psychologist who had conducted the research was later kicked out of the American Psychological Association for his research practices. In 2007, another attempt was made to ban gay adoption in the state legislature. Senator Shawn Womack (R- Mountain Home) was the sponsor of the bill in the Senate, where the bill passed 20-7. An interesting exchange occurred on the floor of the Senate between Womack and opposing senators. At one point, while questioning the extent to which the state would go to determine the sexuality of prospective foster and adoption parents, Senator Jim Argue (D- Little Rock) asked Womack, "Are you gay?" Senator Womack responded that he was a "proud heterosexual." When asked if he could prove this assertion, Senator Womack said that he certainly could, but not in mixed company (Kellams 2007). Despite the colorful debate and the passage of the bill in the Senate, questions about the bill's constitutionality by Governor Beebe resulted in the bill's failure in the House.

As a result of these legislative and judicial failures, the conservative political action group, the Arkansas Family Council, filed a proposal to place an initiative banning gay adoption on the ballot.[11] Attorney General Dustin McDaniel denied the wording of the initiative because it included statements of value instead of statements of policy. An article in the Arkansas Democrat-Gazette on October 5, 2007, explains that, after the wording was adjusted, the initiative was approved for the qualifying stage.

In accordance with Amendment 7 of the Arkansas Constitution, initiative sponsors had to collect signatures totaling 8% of the number of votes cast in the previous gubernatorial election, in this

[8] Examples such as this have led critics to argue that initiatives open the policy-making process to uninformed voters who are easily influenced by deceptive campaign information and could even be convinced to cast a vote against their own interests. A great deal of research has analyzed the allocation of resources by interest groups and political parties in order to influence voters to cast a ballot in favor of a group's agenda (Stigler 1971; Peltzman 1976; Becker 1983).

[9] While turnout may be higher, there may be ballot dropoff (leaving ballot questions blank down ticket) due to voter fatigue. In one survey, one-third of California voters polled in 1989 indicated that the more measures that were listed on a ballot, the more discouraged voters felt about casting their vote (Darcy and McAllister 1990). In another study, Bowler, Donovan, and Happ (1992) recognized the existence of voter fatigue while also pointing out that initiatives raise the level of information in an election as the initiative process requires sustained attention on the part of activists.

[10] In what would become an interesting precursor to the initiative collateral effect on the ability of some heterosexuals to adopt children as a result of the language of the anti-gay policy, the policy of the Review Board (Rule 200.3 Section 2) also "prohibits people with a homosexual adult member of their households from becoming foster parents (Shurley 2002)."

[11] The Arkansas Family Council is a conservative education and research group that performs advocacy work that "promotes family values." The Council works closely with Focus on the Family, a national anti-gay Christian organization that has supported gay marriage bans and similar gay adoption bands across the United States.

case 61,974 signatures, in order to place the initiative on the ballot. The Unmarried Couple Adoption Ban faced heavy opposition from various groups, including Arkansas Families First and Arkansas Advocates for Children and Families. The Arkansas Family Council originally submitted 65,899 signatures but fell short of the requirement after many signatures were thrown out during the validation process. Proponents of the initiative were given the standard 30 days to submit the needed signatures. On August 21, 2008, the group submitted additional signatures, now totaling approximately 84,000, easily meeting the requirement to place the initiative on the November ballot.

The Unmarried Couple Adoption Ban appeared on the November 2008 Arkansas state ballot as Initiative Act 1. The citizen-initiated state initiative passed with 57% of the vote (Arkansas Elections Division). The Arkansas News Bureau reported that the new statute banned all cohabitating couples who were not legally married from adopting or providing foster care for children. The proposed law was intended to apply specifically to same-sex couples but also affected all otherwise qualified couples who were cohabitating outside of marriage (Division for Children and Family Services).

After the passage of the initiative, an organization called Know Thy Neighbor (KTN) endeavored to expose the supporters of the Unmarried Couple Adoption Ban by publishing their names and signatures online. KnowThyNeighbor.org is a grassroots lesbian, gay, bisexual, and transgender (LGBT) advocacy website that uses the Internet to provide a publicly accessible database of every individual that signs an anti-gay initiative for state ballots. Started in 2005, KnowThyNeighbor.org has now added the names and personal information, all of which is already public information[12], of signatories to anti-gay initiatives in Arkansas, Florida, and Massachusetts.[13] KTN intended to include the signatures of petition signers for an anti-gay initiative in Oregon as well. However, the initiative failed to collect enough signatures to qualify, so the names were not posted on the KTN website. KTN operates under the belief that "citizens who sponsor an amendment to take people's rights should never be allowed to do so under the cover of darkness" (KnowThyNeighbor.org). As part of this mission, on April 28, 2009, KTN posted the names and addresses of the individuals who signed the Arkansas Initiative Act 1 Petition, which is public information in the State of Arkansas. Although many Arkansans decried KTN's actions as "intimidation" aimed at stifling the democratic discourse, the Secretary of State maintained that KTN's actions were within the parameters of petition and privacy laws (Wickline 2009).

For the first time, access to this data allows political scientists to study the voting behavior of initiative petition signers. Any attempt to do so in the past was clouded by the inherent limitations of self-reporting: individuals are more likely to be dishonest about controversial issues such as signing anti-gay petitions. The KTN website data allow an analysis of the relationships between petitions, initiatives, and voter turnout in a more objective manner.

Methodology

Hypotheses

I expected to find that engagement in the initiative petition process, specifically the act of signing the Arkansas Initiative Act 1 petition, would have a strong relationship with voter turnout. In other words, registered voters who signed the initiative petition and were thus engaged in that electoral cycle would have been more likely to vote in the November 4, 2008, election than the general population of registered voters. This finding would have been in agreement with existing research that shows that exposure to ballot issues and candidates, as well as voter contact, has a positive effect on one's propensity to vote (Goldstein and Ridout 2002; Lassen 2005). As voters are contacted and informed about an issue on the ballot, they are then engaged in the political process. This engagement includes a greater awareness and understanding of political coverage in the media and a sentiment of personal connection to a ballot issue. The initiative process takes citizens and makes them political actors who are involved in the process of the initiative's passage.

Further, I expected to find that this relationship was similar in strength to the well-documented connection between demographic characteristics (in this study, age, gender, and vote history) and voter turnout (Barreto, Marks, and Woods 2004; Southwell and Pirch 2003). I proceeded to test the following hypotheses:

$\mathbf{H_1}$ Petition signers will be more likely to vote in the 2008 general election than non-signers.

$\mathbf{H_2}$ Petition signing will have a relative contribution to voter turnout that is similar to the major demographic characteristics studied in existing literature (age, gender, and vote history).

Variables and Data

The dependent variable for this study was voter turnout in the November 2008 election, in which Initiative Act 1 (the Unmarried Couple Adoption Ban) appeared. The source of data for the dependent variable was the list of voters who cast ballots in the November 4, 2008, presidential election in the State of Arkansas. This information can also be attained from the Secretary of State's office. The unit of analysis for this study was the individual.

The independent variables considered were the traditional demographic variables including age and voting history, along with the central independent variable for the study, the act of having signed the petition for Arkansas Initiative Act 1. These variables were included in the voter registration lists held by the state. Unfortunately, other traditional demographic characteristics (race, income, education, etc.) were not known, as they were not recorded in the voter registration files. The list of registered voters in the State of Arkansas obtained from Secretary of State Charlie Daniels's office is a dynamic list, updated continually as more voters register. This study required a static list, however, current as

[12] This information is public in the State of Arkansas according to the Arkansas Freedom of Information Act (FOIA), also known as Act 93 of 1967.

[13] Yardley reports that KTN has also attempted to publish the information of voters who signed the unsuccessful anti-gay referendum in Washington State. A lower court ordered the Secretary of State not to disclose the sensitive private information of signers, though this decision was overturned by a Circuit court and then restored by the United States Supreme Court (Biskupic 2010).

of October 6, 2008 (the last day that voters could register in order to vote in the November 4, 2008, elections according to Arkansas state law). For this reason, the list of registered voters from the Secretary of State was manually reduced to only those voters registered by the requisite date.

This study took a small point of departure in dealing with vote history. I examined both a "blunt" and a "nuanced" measurement of previous voter participation. The "blunt" vote history variable was calculated based upon participation in the 2006 election. The "nuanced" vote history measurement was a summative index of participation in the 2000, 2002, 2004, and 2006 elections. Participating in each election assigned a voter one point which, depending on the number of elections in which the voter participated, combined to designate the individual's vote history strength as 0, 1, 2, 3, or 4.[14] Age was calculated using the date of the 2008 election (November 4, 2008) and subtracting the date of birth of the registered voter. The central independent variable, the act of signing the petition, was derived from the KnowThyNeighbor.org database of individuals who had signed the petition to place Arkansas Initiative Act 1 on the 2008 general election ballot.

The Process

Using a random number generator, a random sample of 500 registered voters in 2008 was drawn from the list, provided by the Arkansas Secretary of State's office, of 1,364,832 registered Arkansas voters in the fall of 2008.[15] These names were then manually compared to the list of Initiative Act 1 petition signers on the KTN database. The KTN website allows users to type in the first and last names of any individual to see if he or she signed the petition.[16] Individuals were then coded as either having signed the petition (1) or not having signed the petition (0). Finally, the names of the randomly drawn registered voters were compared to the state voting records for the November 4, 2008 election to identify whether the individual had (1) or had not (0) voted in the election. In addition, individual demographic characteristics of age and vote history, provided by the voter registration lists, were documented.

The final data set of 500 registered Arkansas voters was then analyzed using logistic regression. The relative strength of the relationship between petition signing and voter turnout was then compared with the relative strength of the relationship between the available demographic variables and voter turnout.

Results

Descriptive Findings

Of the 500 randomly picked registered voters in Arkansas, 30 voters had signed the petition to place Initiative Act 1 on the 2008 ballot. One voter was coded as "unknown" due to an error in the Know Thy Neighbor database. This number represents 6% of the total sample. It is not considered low, as the threshold to qualify an initiative for the ballot is 8% of voters.

The sample was composed of 247 registered female voters and 236 registered male voters; the gender of 17 individuals was not coded. The sample of voters ranged in age from 18 to 95 years, with an average age of 49.5. Of this sample, 255 had voted in the 2000 election, 234 had voted in the 2002 election, 345 had voted in the 2004 election, and 280 had voted in the 2006 election.[17] In addition, 390, or 78%, of the sampled voters had voted in the 2008 election. When the nuanced approach to vote history was calculated, the average voter received a vote history of 2.51, indicating that the average voter had taken part in just over two general elections since 2000.

Of the 30 petition signers, 22 of them (73.3%) were Sunday or Wednesday signers listing addresses with non-sequential house numbers, ruling out neighborhood canvassing as the technique that secured their signature. Three individuals were coded as "unknown" due to missing copies of their original signature and date of signing. While the issue of "Sunday and Wednesday signers" was not the focus of this study, it may be worth future exploration. It is clear, not just from the list of petition signers but also from the public statements of Initiative Act 1's supporters, that proponents targeted Christian voters as their base of support in qualifying the initiative.[18] This high proportion of Sunday and Wednesday signers in this study lends evidence to the claim that anti-gay initiatives are largely "Christian" initiatives and further suggests that faith communities continue to be strongly engaged in the political process, especially when it comes to issues of social significance.

There was a significant difference in voter turnout between signers and non-signers, with 93.3% of the signers voting in the election as contrasted with 77.7 of the non-signers ($X2 = 4.31$, $df = 1$, $p < .05$). Viewed from another perspective, petition signers were

[14] The handful of 2008 registered voters who were too young to have voted in 2006 was coded as ineligible. Additionally, county clerks in Arkansas do not operate uniformly in recording voters' registration dates. For this reason, some individuals voted in elections predating their "registration date," most likely because they re-registered to vote and the new date was not reported to the state.

[15] There were 6,692 cases on the SOS-provided dataset in which voters had registered after the cut-off for the 2008 general election, making them ineligible to vote that year. These voters were removed from the pool before the 500 random voters were drawn for this study.

[16] KTN links these names digitally to the original petition signatures.

[17] Fifty-seven voters were declared "ineligible" to vote as of the 2006 election. Many of these individuals had been too young to vote in the 2006 and previous elections or had registered after the qualifying date. As the practice of declaring sampled individuals as "ineligible" was extended to the 2004, 2002, and 2000 elections, the data continued to shift. For the purpose of this study, and to maintain a sizeable sample, "ineligibility" was only calculated for the 2006 election.

[18] Andrew DeMillo of the Associated Press reports on public comments by Jerry Cox, president of the Arkansas Family Council, which sponsored Initiative Act No. 1, in which he stated that churches would be a key canvassing ground for the necessary signatures to qualify the initiative.

15 times more likely to vote than not to vote, while non-signers were only three times more likely to take part in the election than to stay home.

Bivariate Analysis

Table 1 shows the strength of the correlation between each individual variable and voter participation in the 2008 general election. There were statistically significant positive correlations between signing and voting in the 2008 election and between vote history (both blunt and nuanced) and voting in the 2008 election. There were no significant correlations between either age or gender and voting in the 2008 election.

Both blunt and nuanced measurements of vote history were significantly correlated with signing (respectively, Kendall's tau_b = .122, p = .005; Kendall's tau_b = .103, p = .015). Thus voting history and petition signing were closely linked in the sampled voters.

Table 1. Correlation and significance of the correlation between the variables of the study and voting in the 2008 general election.

Variable		2008 General Election
Signed	Kendall's tau_b	.093*
	Significance	0.019
Vote History- Blunt	Kendall's tau_b	.368**
	Significance	0
Vote History- Nuanced	Kendall's tau_b	.322**
	Significance	0
Age	Kendall's tau_b	-0.042
	Significance	0.177
Male	Kendall's tau_b	-0.017
	Significance	0.354

N=500

** Correlation significant at 0.01 level (1-tailed).

* Correlation significant at 0.05 level (1-tailed).

Multivariate Analysis

Table 2 shows the logistic regression estimates for our model of voting behavior in the 2008 general election when using the blunt approach to vote history. Only two variables had a significant relationship (at a threshold of alpha = .05) with voter turnout in the 2008 election: age and vote history. In line with existing literature, vote history was the strongest predictor of voting behavior in the 2008 general election. Petition signing did not appear to contribute significantly to voter turnout. While signing and turnout were correlated at the simple bivariate level, controlling for vote history in the multivariate analysis made clear that turnout and petition signing only appeared to be related because they were both strongly related to the same variable (vote history).

Table 3 also shows the same relationships using the nuanced approach to vote history as opposed to the blunt approach used in Table 2. There are interesting differences between the two calculations. Petition signing moves closer to a level of statistical significance when vote history is measured in a more nuanced manner.

Table 2. Relative significance of variables in determining voter turnout in 2008 General Election in Arkansas, logistic regression estimates (blunt measure of vote history.)

Variable	Hypothesized Direction	Coefficient	Standard Error	Significance
Baseline Probability				
Signers	+	1.056	0.778	0.175
Voter History				
Blunt	+	1.97	0.271	0.000**
Age	+	-0.015	0.008	0.040*
Male	+	-.054	0.248	0.829

**. Significant at the 0.01 level (1-tailed).

*. Significant at the 0.05 level (1-tailed).

N= 427

In other words, when vote history is defined in more conservative terms with a wider sample (the previous four elections as opposed to only the 2006 election), the relationship between signing and voting begins to move toward a point of significance. This is, perhaps, a more accurate way of determining the actual strength of a voter's history of electoral participation, especially in Arkansas, where the 2006 election drew more voters than would normally participate in a non-presidential election year because, for the first time in decades, the gubernatorial race did not include an incumbent.[19]

Table 3. Relative significance of variables in determining voter turnout in 2008 General Election in Arkansas, logistic regression estimates (nuanced measure of vote history.)

Variable	Hypothesized Direction	Coefficient	Standard Error	Significance
Baseline Probability				
Signers	+	1.253	0.777	0.107
Voter History				
Nuanced	+	0.656	0.097	0.000**
Age	+	-0.018	0.007	0.016*
Male	+	0.053	0.245	0.829

**. Significant at the 0.01 level (1-tailed).

*. Significant at the 0.05 level (1-tailed).

N= 427

The relationship between age and voter turnout in the 2008 general election is particularly interesting because of its direction. Of the voters sampled in this study, younger individuals were more likely to vote than older individuals, creating a negative relationship between age and voter participation. Generally, age tends to have a positive effect on voter turnout (Wolfinger and Rosenstone 1980). Increased participation among older voters is explained as part of the "life-cycle" model, in which older voters are more integrated and invested in the community, while younger voters

[19]The 2006 election was the first in 28 years to have an open election for governor in Arkansas (Blomeley 2006). Our vote history data appear to validate this claim of inflated turnout, as 2006 had an unusually high number of voters for a midterm election, at least among the 500 sampled voters.

are more mobile and less integrated. The fact that the data do not support the general model of age and voter participation is clearly important.

Discussion

The data in this study suggest that there is not a significant relationship between petition signing and voter turnout. The implications of these findings are not game-changing but are nonetheless important. Previous studies have revealed that higher voter turnout is a result of an initiative's presence on the ballot during general elections (Smith 2001; Lacey 2005). Until now, no attempt has been made to determine which aspect of the initiative process (e.g., the qualifying stage, the increased media attention as a result of the initiative's presence, increased issue saliency, etc.) caused the increase in turnout. While this study does not identify the aspect of the initiative that mobilized voters, the initial results do encourage a conclusion that removes the qualifying stage (at least among signers) from the list of possibilities.

It is possible that more nuanced measures of voter history, coupled with additional demographic data, would provide different perspectives on the relationship between petition signing and voter turnout. Future studies should draw a larger sample of registered voters and carefully remove ineligible voters, election by election, in order to create a precise measure of vote history. The result may be the discovery of a relationship between the two variables, especially for those who vote intermittently or infrequently, as these voters are most likely to be affected by petition signing if it is indeed a viable method of voter engagement. Research shows that the majority of voter mobilization tactics are most successful among intermittent ("every two years" or "some elections") voters as opposed to regular ("every election") voters or traditional non-voters (Niven 2004; Parry, et al. 2008).

The findings of this study do not greatly affect the use of the initiative by political parties or interest groups in their efforts to turn out their ideological bases. This research does, however, indicate that the qualifying stage is perhaps less productive to any specific cause than other aspects of the initiative process (aside from the necessity of this stage in placing the initiative on the ballot). For this reason, parties should focus more on other aspects of the initiative process if they intend to make it a tool of mobilization.

The data, especially the strength of the correlation between vote history and petition signing, lend merit to a traditional maxim of political engagement: participators are participators. Individuals with strong histories of voting in elections tend to be the most engaged, not only in future elections but also in the process of qualifying initiatives. The dynamic of initiative petition signing and voter turnout do not appear to have the hypothesized effect. The conclusion is not that individuals who sign petitions are more likely to become better engaged as voting Americans but that voting Americans are more likely to sign petitions to qualify ballot initiatives that deal with issues on which they hold strong opinions.

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Mentor Comments: Professor Janine Parry's enthusiasm for the work of her student is evident in this glowing commentary.

Shayne Henry is among the most vibrant, sincere, and talented students with whom I have come into contact in 17 years of college-level instruction. You might imagine my delight when he emailed me from his study abroad program in Granada, Spain (where he was studying Islamophobia in southern Europe) last spring to ask if I would be interested in advising his honors research. He expressed a desire to focus, broadly, on the treatment of gay rights in the American states. Not only is this field of great interest to me and is there much to learn, but Shayne is the sort of student we hope will invite us to advise a thesis project. The proposal he developed was excellent and early to take form AND the work has both scholarly and practical value. Specifically, we took advantage of data recently made available by a public interest group known as "Know Thy Neighbor." The group has grabbed headlines in recent years for making available, through a searchable database posted online, the names of hundreds of thousands of registered voters who signed petitions qualifying anti-gay rights measures for state general election ballots in Massachusetts, Florida, Arkansas, and (perhaps … see the Doe v. Reed pending before the U.S. Supreme Court at this writing) Washington. These names – together with the mailing addresses, birthdates, and dates of signature – have long been public information but never before have they been put into a format that made them easy to access … and analyze. Our approach for Shayne's paper was to sample the 65,000 signatures collected in support of Initiated Act 1 (to prohibit fostering or adoption by cohabitating couples) in Arkansas. Then, by pulling in verified vote history and other variables from the Secretary of State's voter records, he was able to test empirically the effectiveness of a relatively new tactic in American politics: using ballot measures to stimulate turnout for up-ticket candidate races, like the U.S. presidency. What he discovered was that, although "hot" ballot measures have long been known to boost statewide participation rates by a few percentage points, it does not appear – at this point – to be the singular act of signing by individual voters that causes that aggregate boost. In terms of Shayne's contribution to this extraordinarily original project, it has been substantial. While I guided him to the dataset as we discussed possibilities for a subject related to gays and lesbians and American politics, he was central to formulating the research question (does the act of signing a petition make a person more likely to vote in the subsequent election) and the research design (sampling registered voters, at least those registered in advance of the 2008 general election). He also manually entered about 1500 data points in our spreadsheet and both discovered, and proposed valid remedies to, the usual data glitches revealed in that process. In addition, and I was most impressed by this, he came to the conclusion – based on his true understanding of the extant literature on voter mobilization and independently of my plans to do this very thing – that in future iterations of our project we should see if petition signing DID mobilize infrequent voters even if it did not mobilize regular participators. The leading scholar on this subject, the University of Florida's Dan Smith, and I are doing that very thing in a manuscript based on the same data (with Arkansas and two Florida datasets) and, in keeping with Shayne's informed hunch, it works beautifully. I'm very pleased indeed to see Shayne Henry's important and unique contribution to political science, and contemporary politics, included in this collection.

EVALUATION OF FISH AND MACROINVERTEBRATE INDICES OF BIOTIC INTEGRITY IN THE BIOASSESSMENT OF THE ILLINOIS RIVER BASIN

By Rebekah Hotz
Department of Biological Sciences

Faculty Mentor: Art Brown
Department of Biological Sciences

Abstract

Evaluating performances of the fish and invertebrate Indices of Biotic Integrity (IBIs) for a region is important to maintain rigorous assessment of the environmental quality of streams, especially with increasing urbanization. Timing of the assessment is considered important, with the critical season (low flow, high temperature) preferred, but the primary season (spring – summer) may be as efficient. I assisted with the collection and analysis of fish and macroinvertebrates using methods developed by the United States Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocols (RBPs) and the Arkansas Department of Environmental Quality (ADEQ), along with obtaining habitat and chemical assessments during primary and critical periods during 2007-2009 at ten sites in the Illinois River Basin up and downstream of two wastewater treatment plants (WWTPs). My objectives were to (1) compare fish and macroinvertebrate IBIs for use in the Illinois River Basin; (2) investigate correlations with each IBI and its metrics to nutrient, habitat, and watershed variables; (3) compare the efficacy of the IBIs during both critical and primary seasons; and (4) determine how two WWTPs in the area affect downstream water quality into Oklahoma. The two IBIs were strongly correlated with each other (Rs of 0.59); however, macroinvertebrates outperformed the fish. More regionally specific fish metrics should allow for better performing fish IBIs, but adequate performance was found. Combining the seasons' data allowed for a more comprehensive and statistically significant assessment; however, the primary season evaluated each site comparably to the combined data and generally outperformed the critical seasons. The combined and primary seasons' macroinvertebrate IBIs revealed sites with lowered environmental quality below the WWTPs but with quick returns to reference conditions. My results indicate that it may be possible to test IBIs during only the primary seasons to get efficient water quality and site comparison assessments.

Introduction

With the increasing quantity and diversity of chemical runoff from industrial, agricultural, and urban areas, along with an array of environmental modifications, the water quality of the United States' surface waters has become an increasingly important issue. For this reason, much legislation has been passed in the U.S. to develop a means for monitoring, assessing, and restoring the nation's environmental quality of wadeable streams. However, biological assessments, which use biological surveys and other measures of the biota in surface waters to evaluate water body conditions, only began to be integrated into state and tribal programs a little over three decades ago (Barbour et al. 1999; Yoder and Barbour 2009). Biological criteria usually are more capable of detecting degradation due to anthropogenic influences than are chemical and toxicological methods (Karr 1991). A study in Ohio found that water quality variables did not recognize the presence of human influence, while bioassessments correctly identified influence 49.8% of the time (Kerans and Karr 1994). An array of natural and anthropogenic influences is detectable by fish and macroinvertebrate assemblages due to their integrative response to stress from habitat, water chemistry, and other environmental factors (Weigel and Robertson 2007).

The Water Pollution Control Act (WPCA) of 1948 was passed for the protection of U.S. waters (Dauwalter et al. 2003). In 1972, amendments were made to the WPCA, which is now known as the Clean Water Act (CWA), to include a fishable and swimmable goal and to restore and preserve the physical, chemical, and biological integrity of the nation's waters (Karr 1991). The U.S. Environmental Protection Agency (USEPA) uses Frey's original definition to define biological integrity as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Hawkins 2006).

In 1981, Karr developed the quick, reliable, and easy Index of Biotic Integrity (IBI), which set a framework for bioassessment with its multimetric index using a biosurvey of the fish community (Dauwalter et al. 2003). The USEPA came to believe that, above tedious individual toxicity measurements, biomonitoring approaches could offer significant advantages (Roop and Hunsaker 1985). The USEPA decided to create Rapid Bioassessment Protocols (RBPs) to fulfill the need for concise, cost-effective biological survey techniques for the application of the CWA (Barbour et al. 1999). Karr's IBI was integrated into the RBPs fish protocols, with various regional modifications, since distinct fish assemblages had been shown to correspond with ecoregions, and soon the Invertebrate Community Index (ICI) was created and modified into a benthic IBI for use in the RBPs (Dauwalter et al. 2003; Barbour et al. 1999). The 1989 RBPs were revised in 1999 as Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition for assessment using three assemblages along with habitat for a more comprehensive approach (Barbour et al. 1999).

The current pressing issue is determining appropriate regional modifications of the biometrics since each region may contain differing species richness and composition, trophic composition, and taxa abundance and conditions. Therefore, one series of

biometrics cannot accurately calculate environmental quality for all regions (Barbour et al. 1999).

Effort and cost must be considered for bioassessment. These can be reduced by determining the most effective time(s) to sample in order to minimize samples per year. Seasonality greatly affects streams and their biota; therefore, sample periods usually occur during the critical and/or primary seasons. The critical season usually occurs during the summer of each year and allows for insight into the effects of low flow and high temperatures (> 22°C for northwestern Arkansas), often accompanied by algal blooms (Barbour et al. 1999). The primary season usually entails the less extreme conditions of the spring, with higher flows and cooler temperatures. Sampling both seasons for a combined seasons' dataset is optimal for a more comprehensive assessment; however, past bioassessments have also used only one season, with the critical season usually being the preferred (see ADEQ 2003, Wang et al. 2007, and Dauwalter et al. 2003). If one season's performance is comparable to the combined dataset, effort and cost may be conserved by the use of sampling during only one season for further specificity of the IBI.

With regionally specific IBIs, the individual biometrics can perform optimally; thus, the nation's water quality can be monitored more effectively, and stricter environment protection regulations, especially for industries, can be implemented based on the IBIs' findings in the surrounding surface waters. Therefore, my focus was on evaluating the current IBIs for fish and macroinvertebrate assemblages in the Illinois River Basin on sites around two wastewater treatment plants (WWTPs).

With more understanding of the performance of each metric and the overall IBIs, future studies in this region may use the most advantageous IBI metrics to accurately recognize sources of stream degradation in this rapidly urbanizing region and thus help maintain and restore adequate stream health. Currently, the Arkansas Department of Environmental Quality (ADEQ) has a recommended method for performing a fish IBI for the much larger region of Ozark Highlands Streams, which encompasses the Illinois River Basin. For Arkansas' macroinvertebrate communities, the ADEQ has a list of 25 suggested metrics for individual screening. If the current IBI metrics are not found to perform strongly, there will be a need to develop even more specific and discriminatory metrics for the region.

The objectives of this project were to (1) determine how the fish and macroinvertebrate IBIs compare with each other in their use on the streams of the Illinois River Basin; (2) investigate how effectively each IBI and its individual metrics correlate with nutrient, habitat, and watershed variables; (3) determine if it is necessary for bioassessments to sample surface waters during both the critical and primary seasons; and (4) determine how two wastewater treatment plants (WWTPs) in the area affect downstream water quality into Oklahoma.

Study Site

The headwaters of the Illinois River originate in northwest Arkansas in the Springfield Plateau ecoregion within the Ozark Highlands and then flow into northeastern Oklahoma to confluence with the Arkansas River. The Ozark Highlands contain moderately diverse biota in streams formed predominately of alluvial gravel with distinct riffle-pool geomorphometry (Brown and Matthews 1995).

The study sites were in the Illinois River Basin's northwest Arkansas area, which is influenced by agricultural run-off and effluents from the cities of Fayetteville, Springdale, Rogers, Siloam Springs, and Prairie Grove, Arkansas. The Rogers and Springdale WWTPs were the focus of the current study. Five sites (OSG1, OSG2, OSG3, OSG4, and OSG5) were located on Osage Creek, which contains the Rogers WWTP. Three sites (SPG1, SPG2, and SPG3) were located on Spring Creek, which contains the Springdale WWTP, and the two other sites were reference streams on Little Osage (LOREF) and Camber Springs (CSREF). The layout of the ten sites placed upstream of each plant, two sites downstream of each plant, and two sites on Osage Creek below the confluence with Spring Creek (Figure 1). Watershed sizes of the sites varied greatly from 13.4 square km (CSREF) to 209.2 square km (OSG5).

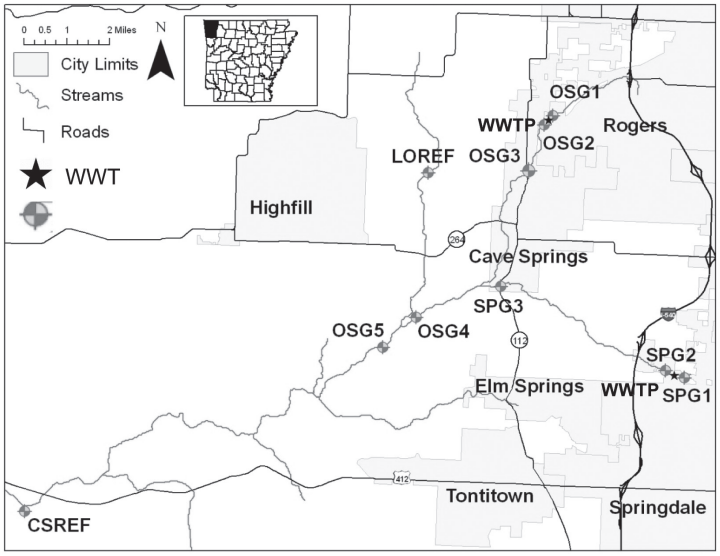

Figure 1. A map of the study area with sample sites and WWTP areas marked. The two reference sites are indicated by their abbreviations: LOREF and CSREF. The sites on Osage Creek EW denoted as OSG; Spring Creek sites, as SPG.

Methods

The methods were adopted from the detailed descriptions in the USEPA's RBPs and ADEQ (Barbour et al. 1999). Fish and macroinvertebrate collections, along with habitat and chemical assessments at all ten sites, occurred in summer 2007, spring and summer 2008, and spring and summer 2009. Summer samples were planned to occur during the critical season of low flow and high temperatures (> 220C) each year; however, there was no critical season during 2008, so the summer 2009 sample was performed to obtain the second critical season sample and replace the summer 2008 data.

Water Chemistry

Another team on which I did not participate collected water samples during base flow conditions a total of 29 times from the summer of 2007 to the summer of 2009, using methods described in the EPA protocols. The nutrient variables used for comparison with biometrics in this study were total phosphorus (TP), total

nitrogen (TN), and total organic carbon (TOC). More details are available in the team's final report (see Matlock et al. 2009).

Habitat and Geomorphology

The qualitative RBP Habitat Assessment approach was used to develop a habitat profile for each sample reach. During each habitat assessment, the biotic canopy cover was measured. Geomorphologic assessments were performed once at each site to define the general morphologic characteristics of the reach, including % reach bedrock. Another team was in charge of these methods, but I occasionally helped with measurements. More details are available in the team's final report (see Matlock et al. 2009).

Watershed Areas and Attributes

Through the Center for Advanced Spatial Technology, University of Arkansas, watershed areas and percent dominant land use areas were found in 2006 for select sites on the Illinois River Basin.

Fish Assemblage Analyses

A 350-1000 foot long reach at each site, representing the diverse habitats of each stream, i.e., riffles, runs, and pools, was used for fish collection through single-pass upstream backpack electrofishing with block nets in accordance with the USEPA's RBPs (Barbour et al. 1999). Three persons with long-handled dip nets followed the electrofisher to collect and transfer the fish to livewells for identification of species, which was performed by the same person every time. Hybrids and anomalies, in addition to species, were documented. After enumeration, the fish were released. If field identification of certain specimens was uncertain, preservation in 10% formalin solution and storage for laboratory identification was performed. Stonerollers (Campostoma spp), which are difficult to identify to species, were usually found in large quantities at the sites. Thus, if there were more than 50 individuals at a site, 40-50 individuals were identified to species, and the ratio was applied to the total number collected at the site. ADEQ's Ozark Highlands' fish metrics were summed to obtain an IBI for each collection at a site (Table 1).

Table 1. Fish community biocriteria for Ozark Highland streams established by ADEQ (ADEQ personal communication).

Metric	5	3	1
% Sensitive Individuals	> 31	31 - 20	< 20
% Cyprinidae (Minnows)	48 – 64	39 – 47 or 65 – 73	< 39 or >73
% Ictaluridae (Catfishes)	> 2	1 - 2	< 1 or > 3% bullheads
% Centrarchidae (Sunfishes)	4 - 15	< 4 or 15 - 20	> 20 or > 2% Green sunfish
% Percidae (Darters)	> 11	5 – 11	< 5
% Primary Feeders	< 42	42 – 49	> 49
% "Key" Individuals	> 23	23 – 16	< 16
Diversity	> 2.77	2.77 – 2.37	< 2.37
# Species	>(watershed area**C**0.034)+16.45	(watershed area**C**0.034)+16.45 to (watershed area**C**0.034)+12.26	<(watershed area**C**0.034)+12.26

[1]no more than 3% bullheads

[2]no more than 2% Green sunfish

Macroinvertebrate Assemblage Analyses

Macroinvertebrate kicknet procedures, as described by the RBPs, were followed (Barbour et al. 1999). Collection occurred from ten locations divided evenly between two riffles in each study site using a rectangular dip net and a slight modification of the single habitat approach described by USEPA (riffles only). Net contents were spread in a large tray at streamside. Invertebrates were picked from samples and placed in 75% ethanol for preservation and transport to the laboratory. In the lab, samples were placed in a 6 cm X 6 cm gridded tray for analysis using the 100″ ± 20% organism collection process in accordance with the USEPA protocols (Barbour et al. 1999). Most of the benthic macroinvertebrates were identified to genus using taxonomic keys. An a priori decision was made to identify the Chironomidae only to family to save the time and money required for further taxonomic refinement. Flat worms and leeches, having been preserved using only ethanol in the field, were not relaxed enough to identify past family or order. Instars too young or too badly damaged (missing legs, gills, mouth parts, etc.) were taken to the lowest taxonomic level, generally family, where certainty of identification was not compromised.

The analysis of the macroinvertebrate data is also rather completely prescribed by the USEPA and ADEQ, although ADEQ is still in the process of completing its decisions about the analysis and interpretation of benthic macroinvertebrate IBI data from the different ecoregions across the state. The methods were followed as closely as possible, and conversations were held with ADEQ personnel regarding items of uncertainty. Eleven biometrics were settled upon for the macroinvertebrate IBI (Table 2). With the top score for each biometric assigned as 5, the highest possible IBI score was 55 since the IBI is the sum of the 11 metric scores. It was necessary for scoring criteria (cut-off values) to be established for the biometrics based on our results. All of our data from critical and primary seasons from all ten collecting locations were used to determine these criteria and to have them correspond to the 25% and 75% quartiles.

Data Analyses

Spearman Rank Correlations (Rs) with $p \leq 0.05$ were used for analysis between the fish and macroinvertebrate IBIs, and IBI and metric correlations were investigated to nutrient, habitat, and watershed variables using JMP 8.0 Software (SAS Institute 2008). The three datasets of critical seasons, primary seasons, and combined seasons were used for IBI and metric correlation investigations. The nonparametric Spearman procedure was used to reduce the effects of the assumption of normal data distribution. This statistical method is commonly used for determining correlations between biotic measures and human influence variables (see Wang et al. 2007, Weigel and Robertson 2007, Bramblett et al. 2005, Dauwalter et al. 2003). Since greater numbers of tests cause greater Type I family-wise error rates, the False Discovery Rate (FDR) was performed to adjust the p-values

Table 2. Macroinvertebrate metric scoring ranges established using the 25th and 75th percentile rankings of metric scores from all five collections performed during this study. Invertebrate metric scoring ranges for the Osage and Spring Creek basins of the Illinois River, Arkansas, is shown in A). B) shows percentile ranking of metric used to establish scoring ranges for each of the biometrics. Note that the % Isopoda metric was changed from "0.0%" indicated by the 25th percentile to "< 2" following our best professional judgment. EPT stands for Ephemeroptera, Plecoptera, and Trichoptera Taxa, while HBI is the Hilsenhoff Biotic Index.

A)

Metric	5	3	1
Total Taxa	> 17	17 – 12	< 12
Number EPT Taxa	> 8	8 – 5	< 5
%EPT- %Hydropsychidae	> 55	55 – 28	< 28
% Scrapers	> 33	5 – 33	< 5
% Clingers	> 68	68 – 23	< 23
% Diptera	< 4	4 – 24	> 24
% Chironomidae	< 3	3 – 22	> 22
% Isopoda	< 2	2 – 7	> 7
% Tolerant Organisms (7-10)	< 2	2 – 12	> 12
HBI	< 4.1	4.1 - 5.2	> 5.2
% Intolerant Organisms (1-3)	> 24	24 – 6	< 6

B)

Metric	Min	5th	25th	50th	75th	95th	Max
Total Taxa	8	8.45	12	15	17	19.55	23
Number EPT Taxa	2	2.45	5	6	7.75	10.55	14
%EPT- %Hydropsychidae	4.1%	9.3%	28.0%	44.4%	55.3%	67.1%	73.6%
% Scrapers	0.0%	0.0%	4.5%	17.1%	33.1%	48.4%	60.6%
% Clingers	2.8%	5.8%	23.4%	48.7%	67.7%	84.8%	92.1%
% Diptera	0.0%	0.0%	3.9%	10.6%	23.9%	55.9%	66.7%
% Chironomidae	0.0%	0.0%	2.5%	7.2%	21.6%	44.3%	57.5%
% Isopoda	0.0%	0.0%	0.0%	0.4%	6.8%	55.2%	72.5%
% Tolerant Organisms	0.0%	0.0%	1.7%	3.3%	12.1%	53.9%	67.0%
HBI	2.59	3.11	4.11	4.76	5.15	6.40	6.89
% Intolerant Organisms	0.0%	1.9%	5.7%	12.5%	23.8%	52.8%	64.7%

for each Spearman Rank Correlation set of tests performed (Quinn and Keough 2002). Analyses of Variance (ANOVA) in conjunction with the Tukey-Kramer Honestly Significant Difference test were used for comparisons between sites and are common methods of determining significant differences between means (see Bramblett et al. 2005, Barbour et al. 1999, Kerans and Karr 1994).

Results and Discussion

Fish IBI and Macroinvertebrate IBI Analyses

Fish IBI scores were significantly positively correlated with macroinvertebrate IBI scores (Rs of 0.59, $p < 0.0001$) (Figure 2). The strong correlation may indicate that the assemblages were similarly affected by degradation in their environments and the IBIs were both detecting this degradation. It is pleasing that the assemblages are comparable and do not have conflicting water quality results.

Further investigation of each IBI with nutrient, habitat, and watershed variables allowed for a deeper understanding of the effects of degradation on each assemblage; however, cause-and-effect relations could not be established using this analysis. First, the combined dataset was used to see how the IBIs correlated with the nutrient variables of Total Phosphorous (ranging from 0.029 to 0.643 mg/L, mean of 0.112 mg/L), Total Nitrogen (ranging from 0.47 to 7.37 mg/L, mean of 4.00 mg/L), and Total Organic Carbon (ranging from 0.15 to 4.16 mg/L, mean of 1.15 mg/L). The fish IBI did not have any significant correlations; however, the macroinvertebrate IBI was significantly negatively

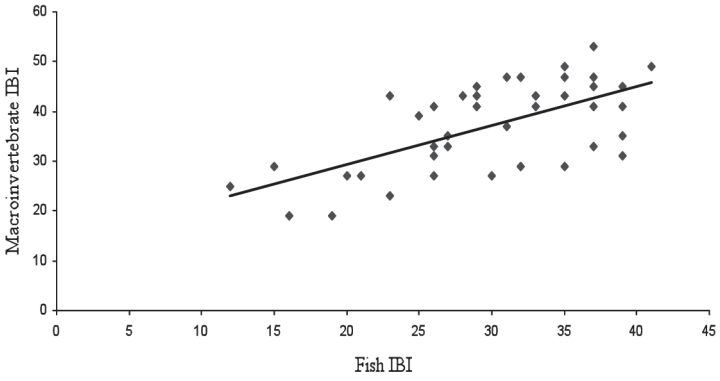

Figure 2. The significant and strong correlation between the fish IBI and the macroinvertebrate IBI is graphically visible, with an Rs of 0.59 and p values much less than even 0.0001.

correlated to Total Phosphorous (Rs = -0.47) and Total Organic Carbon (Rs = -0.50). Nitrogen correlation was completely absent in both assemblages. Next, testing with the habitat variables of the RBP Total (ranging from 120 to 179, mean of 151), % Reach Bedrock (ranging from 0 to 35%, mean of 9%), and Biotic Canopy Cover (ranging from 2.7 to 78, mean of 44) showed that both assemblage IBIs were significantly positively correlated with the RBP Total (fish IBI Rs = 0.58, macroinvertebrate IBI Rs = 0.63). However, the macroinvertebrate IBI also was significantly negatively correlated with % bedrock (Rs = -0.42). With the watershed variables of % urban (ranging from 0 to 60%, mean of 35%), % pasture (ranging from 23 to 79%, mean 43%), and % forest (ranging from 12 to 62%, mean of 19%) tested next, both IBIs correlated significantly to all variables, with % urban being the strongest for both assemblages (fish IBI Rs = -0.73, macroinvertebrate IBI Rs = -0.77) and % forest being the weakest (fish IBI Rs = 0.37, macroinvertebrate IBI Rs = 0.34). Percent pasture showed an Rs of 0.51 for the fish IBI and 0.43 for the macroinvertebrate IBI.

In this study, it appeared that the macroinvertebrate IBI performed better to detect overall degradation since the macroinvertebrate IBI correlated slightly better with the habitat and watershed variables, while at the same time also correlating with nutrients. The fish IBI, however, did not. The macroinvertebrate IBI lacked only the two correlations of Total Nitrogen and canopy, while the fish IBI lacked Total Phosphorous, Total Nitrogen, Total Organic Carbon, % bedrock, and canopy. The better performance of the macroinvertebrate IBI may be due to its being created specifically for the study region through the use of these combined data. The fish IBI was created by ADEQ for the large Ozark Highlands Region. The smaller geographic specificity of the fish IBI may account for the decreased accuracy of detection. In addition, this variety in response may be partially explained by differences in each assemblage's lifespan. Fish indicate more long-term degradation, while invertebrates indicate short-term environmental variations (Barbour et al. 1999). In addition, the different performances might be due to fish being considered reliable indicators of habitat quality and alterations in flow while macroinvertebrates are commonly used for determining the effects of organic pollution and alterations in hydromorphology (Johnson et al. 2006).

The individual seasons' IBI correlations to variables were also investigated to determine if only one season would yield a wide-ranging bioassessment. This investigation involved testing the smaller sample size of 20 for the individual seasons as compared to 40 for the combined. It should be noted that the larger the sample size, the more statistically reliable the correlations are. For the nutrient variables, the only correlation occurred in the critical season with the macroinvertebrate IBI to Total Organic Carbon (Rs = -0.58). For the habitat variables, the only significant correlations occurred during the primary season, with both IBIs to the RBP Total (fish IBI Rs = 0.67; macroinvertebrate IBI Rs = 0.85). For the watershed variables, both IBIs were significantly negatively correlated to % urban in both seasons (fish IBI Rs, -0.74 for critical and -0.76 for primary; macroinvertebrate IBI Rs, -0.70 for critical and -0.84 for primary). However, it was only in the primary season that both IBIs were significantly positively correlated to % pasture (fish IBI Rs = 0.53; macroinvertebrate IBI Rs = 0.50). The primary season had stronger and more significant correlations than the critical season in all areas except for the critical season's single nutrient correlation. Even though the primary season's significant correlations were stronger than the combined data, the season did not compare to the larger number of significant correlations found in the combined data (i.e., three versus seven correlations for the macroinvertebrate IBI). More on individual season contributions will be discussed later.

Fish Metric Analyses

First, the nine metrics of the fish IBI were tested against the nutrient variables. In keeping with the fish IBI results, the metrics never significantly correlated with any nutrient variables in any dataset. The habitat variables showed significant correlations to the metrics. The combined dataset had eight significant correlations within the five metrics of % Sensitive Individuals, % Ictaluridae, % Centrarchidae, % Primary Feeders, and % Key Individuals (Table 3). Although the fish IBI were lacking, there were significant correlations to both % bedrock and canopy among the fish metrics. Half of the significant correlations were to the RBP Total. With the critical dataset, only the three metrics of % Sensitive Individuals, % Primary Feeders, and % Key Individuals were significantly correlated, and of the total of four correlations, none were to % bedrock. The primary season had only a single significant correlation of % Key Individuals to the RBP Total (Rs = 0.76), possibly further presenting this metric as the best indicator of qualitative habitat health at any time during the year. Overall, over half of the fish metrics detected habitat variables with the combined data.

The watershed variables using the combined dataset had seven significant correlations within the four metrics of % Sensitive Individuals, % Ictaluridae, % Primary Feeders, and % Key Individuals (Table 4). Over half of the correlations were to % urban. The loss of sensitive species may be linked to increasing urbanization (Lussier et al. 2008). Indirect nutrient detection may be occurring since increasing urbanization is often linked to increased Total Nitrogen and Total Phosphorous (Campo et al. 2003). With the critical data, there were only four significant correlations within the same metrics as the combined data. The primary season had only one fewer significant correlation; however, only the metrics of % Ictaluridae and % Key Individuals contained the correlations.

Table 3. Correlations among fish IBI metrics from different seasons with habitat variables using A) combined seasonal data, B) critical season data, and C) primary season data. The significant Spearman correlation ($p \leq 0.05$ with FDR correction) coefficients are bolded. The fish metrics are numbered with 1. % Sensitive Individuals, 2. % Cyprinidae, 3. % Ictaluridae, 4. % Centrarchidae, 5. % Percidae, 6. % Primary Feeders, 7. % Key Individuals, 8. Diversity, and 9. Total Species.

A)

Habitat Variable	1	2	3	4	5	6	7	8	9
RBP Total	**0.44**	-0.25	**0.47**	0.13	0.19	**-0.61**	**0.69**	-0.12	0.28
% Bedrock	**-0.52**	0.10	-0.13	**0.48**	-0.21	0.27	-0.18	0.20	0.14
Canopy	0.04	-0.37	-0.16	**0.40**	0.35	**-0.45**	0.39	-0.02	0.26

B)

Habitat Variable	1	2	3	4	5	6	7	8	9
RBP Total	**0.61**	-0.32	0.44	0.21	0.29	**-0.67**	**0.69**	-0.14	0.22
% Bedrock	-0.52	0.13	0.04	0.42	-0.30	0.32	-0.09	0.14	0.09
Canopy	0.29	-0.41	0.06	0.53	0.07	**-0.62**	0.54	-0.08	0.22

C)

Habitat Variable	1	2	3	4	5	6	7	8	9
RBP Total	0.40	-0.26	0.47	0.04	0.21	-0.61	**0.76**	-0.07	0.30
% Bedrock	-0.58	0.09	-0.31	0.50	-0.12	0.21	-0.25	0.24	0.13
Canopy	-0.16	-0.36	-0.37	0.27	0.61	-0.26	0.20	0.05	0.31

Table 4. Correlations among fish IBI metrics from different seasons with watershed variables using A) combined seasonal data, B) critical season data, and C) primary season data. The significant Spearman correlation ($p \leq 0.05$ with FDR correction) coefficients are bolded. The fish metrics are numbered with 1. % Sensitive Individuals, 2. % Cyprinidae, 3. % Ictaluridae, 4. % Centrarchidae, 5. % Percidae, 6. % Primary Feeders, 7. % Key Individuals, 8. Diversity, and 9. Total Species.

A)

Watershed Variable	1	2	3	4	5	6	7	8	9
% Urban	**-0.66**	0.28	**-0.57**	0.03	-0.34	**0.64**	**-0.73**	-0.13	-0.31
% Pasture	0.30	-0.33	0.34	0.24	0.31	**-0.41**	**0.45**	0.23	0.35
% Forest	0.35	0.03	**0.68**	-0.03	-0.27	-0.22	0.32	-0.02	0.14

B)

Watershed Variable	1	2	3	4	5	6	7	8	9
% Urban	**-0.78**	0.42	-0.40	0.02	-0.54	**0.74**	**-0.71**	-0.27	-0.41
% Pasture	0.39	-0.53	0.12	0.17	0.36	-0.43	0.37	0.43	0.32
% Forest	0.45	-0.05	**0.63**	0.05	-0.10	-0.26	0.30	-0.09	0.20

C)

Watershed Variable	1	2	3	4	5	6	7	8	9
% Urban	-0.58	0.21	**-0.73**	0.03	-0.15	0.56	**-0.74**	-0.03	-0.27
% Pasture	0.25	-0.22	0.53	0.29	0.24	-0.41	0.52	0.06	0.41
% Forest	0.26	0.07	**0.72**	-0.08	-0.41	-0.21	0.34	0.04	0.04

The metrics that performed significantly in both the habitat and watershed variables through at least one dataset correlation were % Sensitive Individuals, % Ictaluridae, % Primary Feeders, and % Key Individuals. However, four out of the nine fish metrics were never significantly correlated to any variable in any dataset. These metrics were % Cyprinidae, % Percidae, Diversity, and Total Species. Furthermore, % Centrarchidae correlated only to geomorphology habitat variables instead of anthropogenic variables; therefore, it should be included as a metric that did not perform well towards degradation detection. Overall, fewer than half of the fish metrics performed well for detecting habitat and watershed degradation; therefore, increasing metric performance towards these forms of degradation along with incorporating nutrient degradation detection would strengthen the fish IBI, especially for the regions around the WWTPs. Neither individual season appeared to perform comparably to the combined data for the fish assemblage.

Macroinvertebrate Metric Analyses

Surprisingly, the 11 macroinvertebrate metrics were not

significantly correlated with a single nutrient variable in any dataset. For the habitat variables, the combined data had seven significant correlations within the six macroinvertebrate metrics of Total Taxa; # Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa; % Scrapers; % Diptera; % Chironomidae; and the Hilsenhoff Biotic Index (HBI) (Table 5). Over half of the significant correlations were to the RBP Total. Aligning with the IBI results, the critical season data did not have any significant correlations with habitat variables. Within the primary season data, there were nine significant correlations within the nine metrics of Total Taxa, # EPT, % Scrapers, % Clingers, % Diptera, % Chironomidae, % Isopoda, % Intolerant Organisms, and HBI, each having higher correlations compared to the combined data (e.g., HBI primary data Rs = -0.76 and combined data Rs = -0.46).

Table 5. Correlations among macroinvertebrate IBI metrics from different seasons with habitat variables using the A) combined seasonal data and B) primary season data. The significant Spearman correlation ($p \leq 0.05$ with FDR correction) coefficients are bolded. The macroinvertebrate metrics are number 1. Total Taxa, 2. # EPT, 3. % EPT- % Hypropsychidae, 4. % Scrapers, 5. % Clingers, 6. % Diptera, 7. % Chironomidae, 8. % Isopoda, 9. % Tolerant Organisms, 10. % Intolerant Organisms, and 11. HBI.

A)

Habitat Variable	1	2	3	4	5	6	7	8	9	10	11
RBP Total	**0.67**	**0.53**	0.24	**0.65**	0.39	-0.36	-0.35	-0.38	-0.16	0.37	**-0.46**
% Bedrock	-0.37	-0.31	-0.19	-0.23	-0.02	**0.49**	**0.49**	0.19	-0.09	-0.28	0.24
Canopy	**0.49**	-0.02	-0.09	0.36	0.05	-0.11	-0.14	0.07	0.12	0.16	-0.16

B)

Habitat Variable	1	2	3	4	5	6	7	8	9	10	11
RBP Total	**0.73**	**0.61**	0.47	**0.68**	**0.62**	-0.43	-0.42	**-0.61**	-0.25	**0.68**	**-0.76**
% Bedrock	-0.37	-0.28	-0.15	-0.29	-0.28	**0.64**	**0.61**	0.26	-0.02	-0.27	0.27
Canopy	0.49	0.06	-0.05	0.24	0.22	-0.01	-0.06	-0.04	0.39	0.28	-0.18

The watershed variables had ten significant correlations within the seven metrics of Total Taxa, # EPT, % EPT- % Hypropsychidae, % Scrapers, % Isopoda, % Intolerant Organisms, and HBI through the use of the combined dataset (Table 6). Seven of the correlations were to % urban. With the critical data, there were only four significant correlations to the four metrics of # EPT, % EPT- % Hypropsychidae, % Scrapers, and HBI, with all being only to % urban (i.e., Rs = -0.67, -0.65, -0.63, and 0.69, respectively). The primary season had nine significant correlations within the eight metrics of Total Taxa, # EPT, % Scrapers, % Clingers, % Isopoda, % Tolerant Organisms, % Intolerant Organisms, and HBI. The additional metrics of % Clingers and % Tolerant Organisms were present with the primary data but not present with the combined data; however, the primary data did not show % EPT- % Hypropsychidae performing as it did in the combined data.

Table 6. Correlations among macroinvertebrate IBI metrics from different seasons with watershed variables using A) combined seasonal data, B) critical season data, and C) primary season data. The significant Spearman correlation ($p \leq 0.05$ with FDR correction) coefficients are bolded. The macroinvertebrate metrics are 1. Total Taxa, 2. # EPT, 3. % EPT- % Hypropsychidae, 4. % Scrapers, 5. % Clingers, 6. % Diptera, 7. % Chironomidae, 8. % Isopoda, 9. % Tolerant Organisms, 10. % Intolerant Organisms, and 11. HBI.

A)

Watershed Variable	1	2	3	4	5	6	7	8	9	10	11
% Urban	**-0.59**	**-0.62**	**-0.54**	**-0.61**	-0.34	0.35	0.35	**0.59**	0.34	**-0.60**	**0.66**
% Pasture	0.24	0.26	0.33	**0.39**	0.27	-0.07	-0.08	**-0.52**	-0.34	0.24	-0.30
% Forest	0.20	**0.48**	0.37	0.29	0.15	-0.06	-0.05	-0.23	-0.21	0.27	-0.28

B)

Watershed Variable	1	2	3	4	5	6	7	8	9	10	11
% Urban	-0.54	**-0.67**	**-0.65**	**-0.63**	-0.26	0.50	0.50	0.56	0.20	-0.56	**0.69**
% Pasture	0.17	0.30	0.35	0.47	0.36	-0.18	-0.14	-0.40	-0.26	0.21	-0.35
% Forest	0.25	0.52	0.41	0.40	0.05	-0.10	-0.11	-0.29	0.03	0.25	-0.21

C)

Watershed Variable	1	2	3	4	5	6	7	8	9	10	11
% Urban	**-0.65**	**-0.62**	-0.52	**-0.62**	**-0.57**	0.42	0.38	**0.64**	0.49	**-0.64**	**0.75**
% Pasture	0.31	0.27	0.40	0.37	0.32	-0.01	-0.05	**-0.62**	-0.46	0.28	-0.38
% Forest	0.16	0.44	0.36	0.20	0.23	-0.14	-0.06	-0.22	**-0.62**	0.37	-0.35

Unlike with the fish metrics, every macroinvertebrate metric was significantly correlated to at least one variable category in one of the datasets. Some metrics did, however, have few anthropogenic variable correlations and could be revised. Percent Diptera and % Chironomidae had significant correlations only to the geomorphology habitat variable of % bedrock, based on the combined and primary data. In addition, % Intolerant Organisms significantly correlated only to % forest using the primary dataset (Rs = -0.62); however, it was the only macroinvertebrate metric to ever correlate with % forest, and the metric may be a major contributor to the invertebrate IBI's % forest correlation with the combined data. In addition, % EPT- % Hypropsychidae significantly correlated only to % urban with the combined and critical datasets (Rs = -0.54 and -0.65, respectively). The seven other metrics significantly correlated with both the habitat and watershed variables in at least one dataset, signifying that over half of the metrics performed well towards the IBI for these forms of degradation.

Even though nutrient correlations were not present within the individual metric analysis, the macroinvertebrate metrics' contributions to the macroinvertebrate IBI for the region allowed for degradation detection in all variable categories by the IBI. The macroinvertebrate metrics appeared to perform better overall than the fish metrics. This performance was anticipated due to the use of the data from our study to create the macroinvertebrate IBI. Furthermore, it should be noted that with more data, as mentioned previously, and with more study sites, this study's statistics for detecting nutrient, habitat, and watershed variable correlations to IBIs and metrics would have increased in strength. The individual seasons had dissimilar performances for the invertebrates, which might have been due to the short lifespan affecting sensitivity, especially during the primary season, which appeared to perform comparably to the combined dataset.

Site Comparison Analyses

Due to the finding of the combined macroinvertebrate IBI data for this study having the most significant correlations, best performing metrics, and most statistical reliability due to sample size, the individual sites were first compared for effects along the streams using this assemblage's dataset (see Figure 1 for site map). According to the Tukey-Kramer Test, CSREF had the highest macroinvertebrate IBI mean score (49.5) and was significantly different from all other sites. LOREF had a high IBI score (43.5) and was not significantly different from OSG1 (IBI of 43) and OSG5 (IBI of 43.5); therefore, by this analysis, these sites were at reference condition. After the significant IBI decrease from OSG1 to the effluent of the Roger's WWTP at OSG2 (IBI of 30.5), the means of the IBIs steadily increased back to reference conditions at OSG5, indicating that Osage Creek returned to reference conditions quickly after the WWTPs; thus, the WWTPs did not affect the stream conditions into the Illinois River in Oklahoma. Spring Creek showed that SPG1 was already severely degraded (IBI of 23) and significantly different from all other sites. At SPG2, with the effluent of Springdale's WWTP, there was a significant increase in the IBI; however, this result still signified

strong degradation as indicated by an IBI of 27, which showed 49% health. By SPG3, the IBI of 37 indicated a significantly healthier condition; thus, the confluence with Osage Creek by OSG4 (IBI of 37) did not negatively affect the IBI.

To test whether one season could distinguish between sites in a way comparable to the combined data's distinctions, the Tukey-Kramer Test was performed for each season. The critical season data illustrated no significant differences among sites, while the primary season had the same significant differences as the combined test, with two additional ones along the streams. They included a significant decrease from SPG3 (IBI of 33) to OSG4 (IBI of 35) and a significant increase from OSG3 (IBI of 33) to OSG4 (IBI of 35). The primary season data results did not conflict with the combined data results (Figure 3).

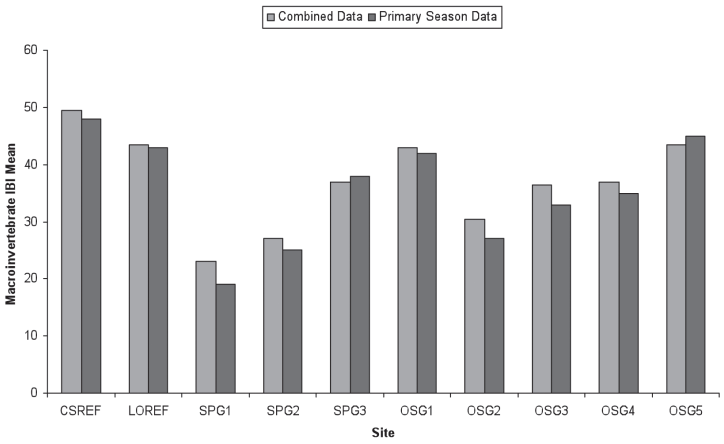

Figure 3. Macroinvertebrate IBI means of the combined seasonal and primary season data for each site.

Investigation of sites using the fish IBI did not show as strong a differentiation among sites as did the macroinvertebrate IBI. With the combined data, the only significant difference along the streams was from SPG1 to SPG3, with increases in means from 15.5 to 23 to 34, and the reference sites were significantly higher than all study sites (CSREF IBI of 38; LOREF IBI of 35). Site comparisons with the individual seasons for fish showed inconsistent results (Figure 4). The current fish IBI seemed to miss many sources of degradation, while the macroinvertebrate IBI was more sensitive to anthropogenic influences. However, revisions to the fish IBI are important, so both fish and macroinvertebrate assemblages can be efficiently used for bioassessment, particularly since together the assemblages complement each other, each having areas of stronger response to stressors (Weigel and Robertson 2007).

Conclusion

For this study on the Illinois River Basin, it appears that even though the fish and macroinvertebrate IBIs correlated strongly with each other and both seemed competent in detecting degradation, the current macroinvertebrate IBI better detected types of degradation, especially when it came to degradation caused by nutrient variables. The individual macroinvertebrate metrics outperformed the fish metrics in their correlations with habitat and watershed variables. For the macroinvertebrate IBI, the suggested metric revisions for the region include less than half its metrics. Due to their lowered number of significant correlations, revisions to % Diptera and % Chironomidae, and possibly % Intolerant Organisms and % EPT- % Hypropsychidae,

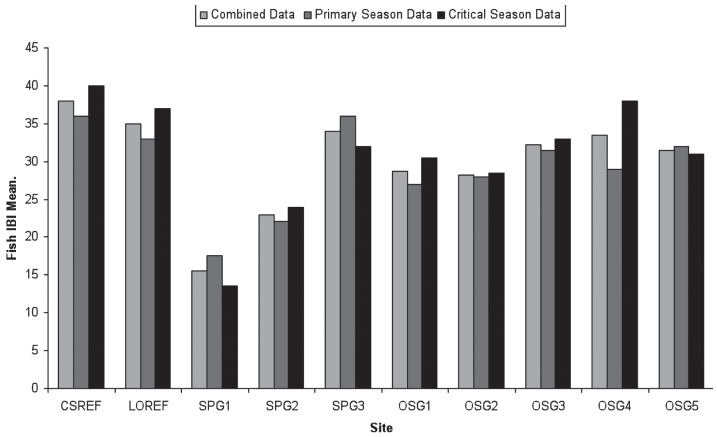

Figure 4. Fish IBI means of the combined, primary season, and critical season data for each site.

could further strengthen the IBI. For the fish IBI, over half of the metrics are in need of revision, either by replacement or slight modifications. These metrics are % Cyprinidae, % Percidae, Diversity, Total Species, and % Centrarchidae.

This study indicated that the most comprehensive bioassessment would use the combined seasonal dataset. However, with the IBIs' variable correlations, the primary season outperformed the critical season, and the macroinvertebrate metrics went on to show this same trend. In contrast, a deeper look into the fish metrics showed the critical season slightly outperforming the primary season. Even so, site comparisons with the macroinvertebrates' combined and primary season datasets were complimentary in indicating that the WWTPs did not affect water quality into Oklahoma. Therefore, for this study, it appeared that the use of only the primary seasons for macroinvertebrate collection was sufficient in bioassessment, particularly for indicating the effects of the WWTPs. For a more thorough bioassessment including all of the possible anthropogenic influences on each site and watershed, the use of the combined data would provide more statistical reliability and a wider range of indications through the distinctive contributions of both seasons. However, the sole use of the primary seasons could be efficient for other studies for a quick bioassessment to determine effects among sites without the need for thorough individual site investigation. More investigation into the use of only the primary seasons for fish and invertebrate bioassessments should be performed in this region and beyond to see if a more cost-efficient and effort-efficient method is possible. Apparently, the use of critical season data is a holdover from times when evaluations were based on only chemical (nutrient, oxygen, etc.) and physical (e.g., temperature) data. Fish and most invertebrate species must endure environmental conditions all year.

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Mentor Comments: When Rebekah originally submitted her manuscript for consideration for the Undergraduate Research Award, Professor Arthur Brown described her tenacity and commitment to working with him on this project. In the following, he provides additional information about her work and its contribution.

Rebekah Hotz tested the performance of the methods being used to evaluate water quality up and downstream of the wastewater treatment plants of Rogers and Springdale, and their potential impact on the Illinois River's water quality as it flows into Oklahoma. The U S Environmental Protection Agency (EPA) and Arkansas Department of Environmental Quality (ADEQ) have been involved in developing methods for biological assessment of stream water quality for nearly 30 years but refinement of the methods is a continuing process and of considerable importance. Water quality of the Illinois River has been the subject of much controversy between Arkansas and Oklahoma for decades. Drs. Marty Matlock and Brian Haggard, from BAEG, and I comprehensively studied the physical, chemical, and biological aspects the Osage Creek and Spring Creek sub-basins of the Illinois River during 2007-2009 to determine whether the Rogers and Springdale wastewater effluents were degrading water quality in the streams, and, if so, whether the water remained impaired as it left the basins and headed for Oklahoma. We used methods prescribed by EPA and ADEQ that have legal standing. I was curious about just how robust those methods were and encouraged Rebekah to test the biological components of them. She chose four objectives for the study described in her thesis. Of those, the first three were items for which she had primary responsibility. She was less responsible for assessing impacts of the wastewater treatment plants. Additionally, Rebekah assisted with seasonal collections of data and fish. Her focus was on performance of the biological assessment tools we were using. She received some assistance from other members of the team, including Eric Cummins (a technician in BAEG that worked with us as a project leader and data analyst), and a statistician. Sharing of expertise and duties is the primary reason to have a team of collaborative investigators. The EPA, ADEQ and other states' agencies are very interested in our study, mostly because of the interstate socio-political conflict associated with it, but also because we have more actual data. Rebekah became an important member of our team by refining and evaluating the methods we used. She undertook and admirably completed a difficult analysis of the biological assessment methods in use in this ecoregion. This required careful (and difficult) statistical analyses of a large amount of data. She was not familiar with the types of data used, collection methods, the indices being used, or the kinds of statistical analyses necessary to evaluate their performance when she began. She learned all of this with minimal guidance and assistance. I provided some literature citations for her initially then she began to give me important papers to read. This is something that I expect of graduate students, but not of honors undergraduate students.

DESIGN STUDIO INVOLVEMENT OF REAL-WORLD STAKEHOLDERS IN THE FAY JONES SCHOOL OF ARCHITECTURE, UNIVERSITY OF ARKANSAS

By Robert Jackson

Department of Landscape Architecture

Faculty Advisor: Carl Smith

Department of Landscape Architecture

Abstract

There is evidence that architecture students are increasingly unprepared to enter the architectural workforce upon graduation. Some research has identified a growing gap between architectural education and architectural practice in terms of real-world concerns as the reason for students' unpreparedness. By involving real-world stakeholders in architectural design studios – by which I mean individuals drawn from outside the academy with a professional, financial, or emotional investment in a project – educators may be able to create a more authentic learning environment that will better prepare students for architectural practice. This study describes my personal experiences as a student working on design projects involving real-world stakeholders, including both benefits and drawbacks. My experiences are set into context by relating the outcomes of six semi-structured interviews with current faculty, current students, and a recent graduate of the Fay Jones School of Architecture at the University of Arkansas, all of whom have participated in school projects involving real-world stakeholders. Generally speaking, students were more engaged when real-world stakeholders were involved in their studio projects, though professors often faced additional challenges in coordinating the stakeholders' participation with the academic schedule. Ultimately, the students interviewed expressed a preference for projects involving stakeholders, believing that such projects bore greater resemblance to projects in architecture practice. Professors, on the other hand, tended to have mixed thoughts regarding the value of such projects. The paper concludes with tentative recommendations about how to best accommodate stakeholder participation into architectural school design projects.

Introduction

As far back as 1954, an American Institute of Architects (AIA) report called for closing a growing gap between educators and practitioners (Bannister, 1954), and many academicians and practitioners alike have commented on not only the disconnect between architectural education and architectural practice but also a similar disconnect between these and real-world concerns. For example, through extensive interviews with practicing architects, Harvard University Education Professor Lee Bolman found that 22% of interviewees regretted that they had not learned to deal better with other people while in architecture school (Porter & Kilbridge, 1981, pp. 293-94, 326). Similarly, in a 1995 speech to the American Institute of Architects (AIA) National Convention, Robert Geddes spoke of the importance of ending the architecture discipline's isolation from non-designers, particularly those who participate in the making of built environments (Geddes, 1995). A 1996 report by Ernest L. Boyer and Lee D. Mitgang adds that architectural education should "foster a climate of caring for human needs" by *inter alia* interacting more frequently with clients and communities (Boyer & Mitgang, 1996).

Some of the quotes from the Boyer and Mitgang report remain relevant to architecture education and practice today. For example, a faculty member of a public Midwestern university wrote of the importance of architects' recognizing their role as designers for people, saying: *"…more knowledge should be gained about the physical needs, emotional needs, and broader social requirements to ultimately make the architecture successful for the users"* (*ibid,* p. 39). A professor at North Carolina State University added that it was critical to teach students the *"importance of group dynamics, interviewing, and listening skills in developing designs that respond to human needs"* (*ibid*, p. 39) and that *"in the end, building to meet human needs means helping architecture students become effective teachers and listeners, able to translate the concerns of clients and communities into caring design"* (*ibid*, p. 40).

Creating a more authentic classroom experience in the design studio has been shown to promote student acquisition of a broader range of professional communication skills, thus helping close the gap between school and practice and, ultimately, practice and public. Historically, a major student complaint in typical architectural design studios has been *"a lack of realism in… scope, economic considerations, and client input"* (Clay, 1974, p. 23). The problem continues today. According to Challis (2002, p. 109), this problem can be resolved by creating an authentic learning environment where "activities represent the types of complex tasks performed by professionals in the field, rather than decontextualized or contrived activities." Authenticity can be added to class projects by giving students more realistic design problems and by providing an audience that has a stake in the project – a 'stakeholder' (Martin-Kniep, 2000). In this context, a stakeholder may be thought of as an individual who is not of the academy but who has a financial, professional, or emotional interest in, or attachment to, an architectural project. A stakeholder may be, for example, a landowner, a neighbor, a community representative, or a consultant engaged to deal with the project professionally in parallel to the students' efforts. Irrespective of whether they are strictly 'the client' (i.e., would be paying for an architectural intervention if the student work were a professional commission) or not, these individuals offer advice, practical assistance related to site information, and a set of views, needs, and aspirations that the student must address while meeting the pedagogical goals of the professor. They are *de facto* stakeholder-clients.

According to Press (1998, p. 236), including stakeholders in the design process can help students make better design decisions while also providing them with experience in effectively communicating with people that are unfamiliar with architecture. In addition, such projects may give students a more realistic experience of what happens in a design office (Clay, 1974). Students have said that these types of projects made it easier for them to imagine themselves working on similar projects in future practice (Roberts & Roberts, 2007) and have commended such an approach for effectively linking theory with practice (Martin-Kniep, 2000). Students have also reported that these types of projects hold their attention well, create discussion, engage them with the topic, and encourage them to take a more active learning approach (Roberts & Roberts, 2007).

Nevertheless, instructors have noted some potential drawbacks to such an approach to architectural education. University of Illinois faculty spoke of the potential conflicts that may arise among students due to differing expectations among professors and stakeholders (Clay, 1974). In Clay's study, the faculty recognized that, in a design office, the final solution was mostly shaped by client input and economic constraints; in contrast, in an educational setting, these factors are not a generally preferred basis for making design decisions.

The existing literature, although scant, seems to be positing two points: first, gaps between architectural education and practice and the general public exist, are potentially problematic, and need to be closed. Second, one approach to meeting this challenge involves the inclusion of real-world stakeholders within architectural schools' studio projects. At first glance, this seems sensible. But what are the actual experiences of undertaking this approach? The literature *does* identify some potential problems. This paper adds to the existing literature by providing a first-person account of one student's experience with stakeholder participation in architectural studios and then placing that account within the context of the experiences of fellow students and professors within the Fay Jones School of Architecture at the University of Arkansas.

Personal Experiences as Research Base

During my studies in the five-year Bachelor of Landscape Architecture degree (BLA) program, I worked on three studio projects involving real-world stakeholders. The first of these involved redesigning the historical business core of a small town (population 1,300); the second focused on the redevelopment of the waterfront of a large city (population 80,000); and the third and most recent project involved a downtown park master plan for a small city (population 14,000). For the business core, the class met members of the local community, the mayor, and board members of a historic tavern museum – the centerpiece of the downtown. For the waterfront design, the class met with the city's parks director, several landowners on and near the waterfront, and the local museum management. The park master plan involved the city's cultural tourism director and its planning and development director.

The business core redesign project was my introduction to working with real-world stakeholders; the class professor had been approached to design an herb garden for a historic tavern. Upon visiting the town, the professor recognized that the entire business district adjacent to the tavern, as well as a nearby park, had potential for a studio design project. The professor organized the initial project brief, where community members – the stakeholders – showed the class around the main street and some of its important buildings, explaining their vision for the town's future redevelopment. Several other students and I then maintained contact with the stakeholders throughout the inventory, assessment, and design phase of the project, using the stakeholders as resources on subjects such as site history, existing uses, and desired program elements.

The stakeholder involvement in this project gave the project a depth that would otherwise have been difficult to achieve. Much of the site's history had been passed down orally and would have been nearly impossible to research through other sources. Moreover, the added pressure of having to present to a large audience of the town's residents inspired me as well as many of my classmates. The project's community service was also a major motivational factor since many of us were from other struggling small towns that faced similar issues. Nevertheless, it seemed to me and some other students that the project's focus was rather confused, as many of the stakeholders were more interested in the design of the herb garden (the initial design they had sought out) than in the design for a downtown master plan, which the professor had suggested. During the final presentation in the town hall, and despite the breadth of scope of the studio output, many of the stakeholders were still inquiring, *"Where is that herb garden?"*

The next project, involving the riverfront redevelopment for the larger city, was initiated as a studio exercise by a visiting professor from a professional design firm. The fact that an architect from a professional design firm was involved probably helped generate stakeholder interest in the project. The stakeholders were the city's parks director, several landowners on and near the waterfront, and the local museum management. As in the small town redevelopment exercise, student involvement in the project started with the stakeholders. Each class member was assigned a specific stakeholder contact and was supposed to use that contact to work on the corresponding component of the site inventory and assessment. My contact was the director of a major national museum which was relocating to the project site. However, this individual did not return telephone calls. The project's visiting professor did incorporate some of the atmosphere of a professional design office into the classroom, much to the delight of the students. In addition, the professors and the students had several discussions about effective communication and presentation techniques with stakeholders, which proved helpful during the final presentation. Perhaps this fact emphasizes the importance of the real-world experience of design professors who can go beyond technical competency and draw on other skills honed in practice. During the final presentation of the project, the stakeholders who were present at the original introduction of the project were also present, and for the most part their comments on the project were very courteous, though it was clear that one of the landowners was unhappy with the proposals (see Figure 1 for master plan developed).

Finally, the project involving the master plan of a small town's downtown park was initiated by a regional cultural tour-

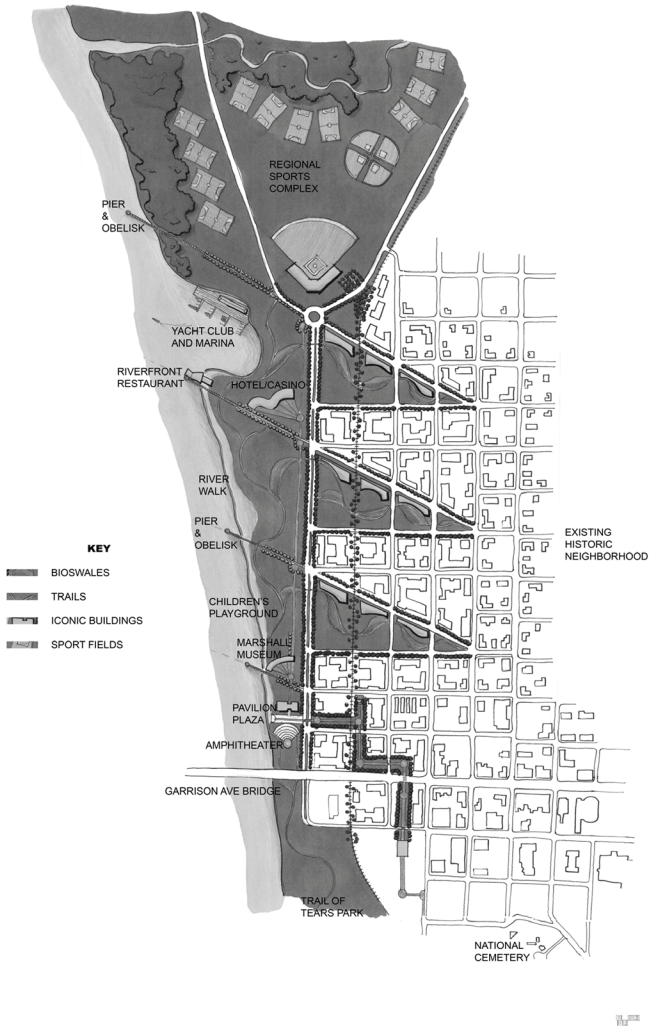

Figure 1. A riverfront redevelopment master plan resulting from stakeholder involvement.

ism director for northeastern Oklahoma who had contacted several nearby landscape architecture schools with his plans for the town's redevelopment. I chose this initiative for my senior design project, which called for minimal stakeholder-professor interaction. Instead, I was the one responsible for taking the initiative in any stakeholder involvement that the project might entail. The initial advice from the tourism director was very helpful as he outlined his desires for the scope and nature of the project. When it became apparent that the part of the project I was most interested in was actually a park owned by the city, the tourism director referred me to the city's planning and development director, who also proved to be very helpful. This individual showed me the park and described in detail her vision for its future, as well as its uses and connections to the surrounding city and what she envisioned its future context would be. Unfortunately it was subsequently difficult to keep in contact with the planning and development director. For example, she did not reply to emails, was not familiar with the project's timetable (discussed on site), and was unable to attend invited presentations and critiques. Apparently, the student project moved at a speed and intensity that made coordination with the planning and development director's time schedule difficult.

Involvement with these real-world stakeholders improved the quality of my work and approach to design. For example, based on my experiences, I made additional efforts to clarify and explain design ideas verbally since many stakeholders are inexperienced at reading drawings. In addition, the projects seemed to take on a new meaning and a higher level of importance since the audiences were not solely professors or peers but members of the community at large.

Additional Research Data

In order to add to the existing literature and set my experiences into context, I collected the experiences and observations of faculty and students within the Fay Jones School of Architecture who had been involved in school studio projects involving real-world stakeholders. A semi-structured interview was selected as the best method of collecting this information from the faculty members and students. This type of interview, which allows respondents to speak freely about a series of themes or topics, is a highly effective and efficient method of gathering information (Smith *et al*. 2009).

Upon approval of the project by the IRB, six subjects were selected to participate in the research project: three professors, two students, and a recent graduate of the school who was working with one of the aforementioned professors as a teaching assistant. The six participants were selected based on their experience involving real-world stakeholders in school projects. Descriptions of the participants and their stakeholder project involvement are provided in Table 1.

Table 1. Research participants and their stakeholder project involvement.

Research interview participant	Project type	Stakeholder(s) involved	Stakeholder involvement
Landscape Architecture Professor	Community master plan for small AR town	Local museum board, Mayor, community volunteers	Initial brief, final review
Architecture Professor	Design/build restaurant project for post-Katrina development in LA.	Restaurant owner	Initial brief, entire design and construction phases
Architecture Professor	Design/build outdoor classroom for elementary school, AR.	School principal	Initial brief, interim and final reviews, all of construction phase
Recent Graduate and Teaching Assistant	Design/build house in impoverished, tornado-damaged neighborhood, AR.	Non-profit, low-income housing organization, future inhabitants	Initial brief, some interim reviews, all of construction phase
Fifth –Year Landscape Architecture Student	Park master plan for large city, AR	City's parks director	Initial brief, site analysis, throughout design process, final review
Fifth –Year Landscape Architecture Student	Park master plan for large city, AR	Director of a non-profit organization	Initial brief, site analysis, throughout design process

Upon agreeing to participate, the participants were each given a list of research topics, giving them a better understanding of the research project and preparing them to formulate answers for the interview discussion. These are shown in Table 2.

I then conducted the interviews in the location of each participant's choosing, following best practice guidelines for semi-structured interviews as outlined by Oppenheim (1992). The interviews were tape recorded, transcribed, and combined into a written discussion of results in collaboration with my research mentor. In the event that a participant did not want his or her interview taped, the interview notes were handwritten.

Discussion of Interview Responses

The students and faculty interviewed held a variety of opin-

Table 2. Research topics discussed during participant semi-structured interviews.

Initiation of the design project – student, professor, or real-world stakeholder.
The nature of the project(s) involving real-world stakeholders and the reasons for the stakeholders' vested interested in the project.
Experiences regarding the stakeholders' interest and enthusiasm in the project(s) and in aiding the students and professors.
Real-world stakeholders affects on the outcome of students' projects.
Points during project(s) where contact was made with real-world stakeholders.
Effectiveness and techniques of communication with the real-world stakeholders.
Student and faculty attitudes toward working with the real-world stakeholders.
Effect of involving real-world stakeholders on a project in terms of student morale.
Conflict of students' obligations to professors and to the real-world stakeholders.
Views on recommending further integration of real-world stakeholders in the student design studio.

ions on the merits of real-world stakeholder involvement in school design projects. Some felt that the benefits to the students and the stakeholders were well worth the added effort. Others, however, noted drawbacks to such projects, some of which they felt were significant. The following discussion addresses the benefits of stakeholder involvement first.

Projects involving real-world stakeholders can provide students with situations in which they may learn skills useful in professional practice. In fact, one reason one of the fifth-year landscape architecture students gave for her added interest in such projects was that she believed it resembled more of what would take place in a professional design office. She also said that the addition of real-world stakeholders in the design process helped her with her presentation skills, especially with regard to building confidence in dealing with people. In addition, she indicated that she received much helpful guidance from her professors on interaction with real-world stakeholders, specifically presentation techniques, meeting etiquette, and response to criticism. The other fifth-year landscape architecture student expressed the opinion that working with real-world stakeholders had helped him be less intimidated by clients. He also commended the professors' instruction over the years on effective practices for dealing with real-world stakeholders on such issues as email versus written letters, public speaking, email etiquette, and other communication skills.

One of the architecture professors also mentioned some of the skills and insights he believed students had learned in his design/build classes for a restaurant in New Orleans, Louisiana. The backgrounds of most of the students in his classes were dramatically different from that of the stakeholder (a restaurant owner from an impoverished inner-city neighborhood), so before meeting with the stakeholder, the students and the professor had discussions about sensitivity to the situation. Ultimately, no conflicts arose between the students and the restaurant owner. In fact, the relationships worked so well that even the marginal students "blossomed," which the professor found empowering.

Yet another skill that students learned through these types of projects was the ability to process the additional outside input from real-world stakeholders. In professional practice, the designer may have to make decisions that run contrary to the client's wishes (if they believe the decision will ultimately be to the client's benefit), and it was the landscape professor's belief that students must be introduced to such dilemmas in a classroom environment under the guidance of a professor. In fact, this professor said that the ability to factor into a project what the client said was one of the most important skills a student could learn from client interaction.

Real-world stakeholder input also provides other benefits to students. One of the interviewed landscape architecture students highlighted the chance to get additional feedback on projects. Specifically, she said involving real-world stakeholders in projects helped her to understand how people were going to move and otherwise interact within the space being designed. In fact, this landscape architecture student believed that the extra feedback was one of the more important parts of real-world stakeholder participation in studio projects. The landscape architecture professor added that, during the final project reviews, she had always found the client feedback to be excellent. *"The clients are going to be nice to the students, they're going to accept the presentations, and they're going to be wowed by the pretty drawings."*

Moreover, during the course of these projects, clients saw the range of possible design solutions that students had proposed, gave valuable feedback during interim critiques, and helped guide the design outcome. A well-done project, said one fifth-year landscape architecture student, is an opportunity to expand the client's thinking. The other fifth-year landscape architecture student referred to this opportunity to educate stakeholders about the landscape architecture profession as a major motivational factor present in such projects. He said that the client would never have even considered that many of the design options proposed by the students were possible. Even though they would never be built, at least they had become a part of a discussion about the possibilities of the site. In fact, both students and professors mentioned that involving real-world stakeholders can enlighten stakeholders on the professions of landscape architecture and architecture. One architecture professor said that these projects *"help people understand the value of what you do* [as an architect] *and help develop a culture of people who know what you do, therefore increasing demand for architectural services."*

Both of the interviewed landscape students cited the community service component in many of the school's student landscape architecture projects as a major reason for their extra interest in such projects. The drawings that result from these projects can be used to help the real-world stakeholder 'clients' obtain grants for capital works and the fees for a practicing landscape architect to realize a project. Similarly, the school's architecture design/build projects also have had a strong service component, which one of the architecture professors believes leads to a stronger student interest in the projects: *"Architecture has such a potential for positive impact on the community,* [and] *the students involved in the* [design and build] *project continue to have a lifetime commitment to community service."* This architecture professor believes the students seem more interested in and content with stakeholder projects compared to typical studio projects that are confined to an

academic setting within a classroom.

Students also indicated they felt additional accountability in projects involving stakeholders, stemming mainly from the involvement of additional people in the project besides their professors. According to one of the fifth-year landscape students, when a professor was the only figure of authority in a project, students tended to focus their efforts on merely earning a good grade rather than striving for good design. She believed that the involvement of stakeholders, on the other hand, drove students to push harder to make people believe that the student was a good designer. She also believed that these types of projects often resulted in design solutions that were more complex and at a larger scale than the client's initial expectations. However, this student still acknowledged that professors were an integral part in helping drive students to exceed client expectations. In fact, during her senior design project, she was encouraged by her professor to almost completely eliminate the client's program and develop another that was deemed by the professor as more ambitious and appropriate for the site. Though perhaps not always the case, in this situation the client was satisfied with the project's outcome.

What then are the drawbacks of stakeholder projects as experienced by the interviewed students and professors? All the interviewed professors agreed that a great deal more work is involved in these real-world projects as compared with contained projects. Even finding appropriate projects where stakeholders can be involved takes considerable effort on a professor's part since the project has to fit into the curriculum's pedagogical objective (in terms of scale, complexity, intrinsic design challenge, etc.). Further, the professor and stakeholder must undergo the often difficult task of finding supporting documents such as base plans, if they exist. Such projects may also require a careful delegation of tasks to the students, again increasing the organizational challenge to the professor. The professor's role regarding task delegation is particularly important in design/build projects since the project must belong to everybody involved in the designing and the building. To this end, a design/build professor said that he made students rotate tasks frequently in order to maximize student involvement and commitment to the project.

Another major issue is the different time schedules of the classroom and the participating stakeholders. The landscape professor recalled a recent project where the client asked to reschedule the review with little notice. Unfortunately, a reschedule was not possible, and the reviews took place without the client, rather undermining the client's role.

Yet another drawback from the real-world stakeholder approach is the confusion that may arise from involving large numbers of additional people. In this regard, the landscape architecture professor believed that the breadth of stakeholder participation needed to be limited. In other words, the general public can rarely be involved simply because getting such a large number of people together at once is a difficult task. This same professor stated that students should consider outside input *"with a grain of salt."* The professor said, *"Keep client contact to a minimum. They can muddy the water so much."* In addition, the professor cannot be present for all student-stakeholder interaction, and as a result the professor can never really know all that has been said and the extent to which a student has been influenced by a stakeholder's statements.

Students also recognized similar drawbacks of stakeholder input. The recent graduate of the architecture program agreed with the landscape professor: instructors should try to limit or completely avoid interactions between students and real-world stakeholders as it can stifle creativity. While working on their design projects, he said, students can use the realism of real-world stakeholder input as an excuse to leave creative ideas unexplored. The graduate had not realized the extent to which real-world stakeholders could constrict the design process until he himself had worked on a school design/build project with a real-world client. However, he did mention that the faculty had eased the situation by making the students realize that real-world restrictions were not the primary concern within this academic setting. The students were encouraged to focus at least equally on creative exploration. At the same time, however, the recent graduate acknowledged that there was still some merit to introducing students to real-world stakeholder interactions before entering professional practice simply because of the added challenge of a new element in the design process.

Another potentially serious drawback with projects involving real-world stakeholders is the conflicting interests between the professors' and the stakeholders' desires for the project outcome. In all cases, the interviewed professors intended that the students should adhere to their project statement (the set of rules, guidelines, and other criteria set by the professor that students must fulfill in order to satisfactorily complete the project). In the case of a conflict between the professors' project statement and some wish of the stakeholder, all of the professors expected the student to respect the primacy of the project statement.

None of the students interviewed, however, seemed to hold the same view as their professors. In fact, the interviewed students generally said they were more apt to follow the stakeholder-client's desires rather than their professor's. One of the landscape students gave a possible explanation, stating that these studio projects were designed primarily for the client and that the professor was merely helping in achieving that effort. Yet another landscape student said that he felt more loyalty to the stakeholder-client than to his professors. He believed that his chief responsibility in the studio project was to devise a solution for the stakeholder-client that was realistic and practical and that fulfilling the project statement for the professor was only a secondary concern. However, the student did mention that typically, if a student fulfilled the stakeholder-clients' wishes, the project brief was fulfilled as well.

All the professors and students interviewed agreed that another critical issue with these types of projects is that stakeholders should be genuinely interested in the project outcome. In projects dealing strictly with design (rather than design *and* build), experiences with stakeholder interest seemed to vary widely. Fortunately, professors and their students had worked together to compensate for a lack of stakeholder interest in their projects, mainly by simulating the input of an imaginary, more involved stakeholder. Based on professors' and students' experiences, though, if the stakeholder initiated the project, he or she was more likely to be

interested in participation.

Design/build projects, on the other hand, seem to require an enormous amount of stakeholder interest from the outset. Without stakeholder interest, most of these types of projects are not possible. As a result, most design/build projects that proceeded beyond the planning stage had sufficient stakeholder interest, and a lack of interest rarely became an issue later in the course of the projects. An example would be one of the architecture professors' recent design/build projects, located in an impoverished, hurricane-damaged neighborhood in New Orleans. Given the gravity of the situation in one of his project sites, he said, *"Everyone was interested in being helped."* As a result, a lack of client interest was never an issue.

Yet another drawback, mentioned by one of the fifth-year landscape architecture students, is that sometimes the stakeholder has an inaccurate vision of the profession's capabilities. Despite help from professors, there is the very real possibility that the client will shrink the student's vision of the project in order to meet the client's expectations. In other words, he said, a student must stay focused on completing a full landscape architectural project rather than merely drawing a horticultural planting plan.

Conclusion and Recommendations

For the interviewees drawn from the Fay Jones School of Architecture at the University of Arkansas, the involvement of real-world stakeholders in projects created a more authentic learning environment. That being the case, and consistent with current literature, stakeholder participation is a way to address the gap between architecture education, architecture practice, and real-world concerns. Students tended to prefer this more authentic approach and believed that they had learned skills that would be of value in a professional office. The professors also noted the benefits of real-world stakeholder projects for students as well as the architectural professions. However, such projects are not without their challenges. Project preparation can require a considerable amount of time and effort for the professors, and the stakeholder-student interaction can result in outcomes contrary to the professor's pedagogical goals. Again, these findings are consistent with the broader conclusions of the existing literature.

Based on personal experiences and the semi-structured interview data gathered in this study, a series of recommendations can be made to make stakeholder projects run smoothly and to ensure that there is a better educational return on a professor's time investment. The professor should consider choosing projects with a strong community service component, which could increase students' interest and emotional investment. Choosing an appropriate, enthusiastic, and engaged stakeholder is also an important factor in a project's success. Ideally, stakeholders should have an interest in both the project's design and the students' education. Ensuring that the students and the stakeholders share the same expectations for the project outcome as the professor is also important. The professor must be aware of the influence that stakeholders can have over the project outcome and must make the students aware that the professor's project brief and pedagogical goals take precedence over any statement or desire of the stakeholder. Of all possible points within the design process in which the stakeholder may be involved, the interim reviews may the most vulnerable in terms of potentially conflicting advice from professor and stakeholder. Prior to these reviews or any other interaction with stakeholders, professors may wish to review communication skills with the students and reinforce the above hierarchy of authority. Finally, students and professors alike must take initiative in stimulating their own creativity and not rely on the stakeholder as a dependable source of design ideas.

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Mentor Comments: Professor Carl Smith describes the unique perspective Robert brought to his examination of learning experiences within the Fay Jones School of Architecture:

Robert's research work was undertaken in fulfillment of a Special Topics class with me in the Fall Semester of 2009. At this time he was also completing his Senior Design Project which had involved collaboration with real-world stakeholders. I understood he found this process rewarding but challenging, reflecting closely the experience of collaborative working in architectural practice. Such exercises have an important role in architectural education: the facilitation of specific project goals; the development of important and transferrable interpersonal skills; and a window on professional practice. That said there are drawbacks to stakeholder collaboration. The literature reviewed here, and the findings of the paper confirm that stakeholder involvement in a design project can muddy the logistical and pedagogical waters.

Robert has gone beyond simply recounting experiences within the Fay Jones School of Architecture, by formulating some well-needed suggestions on how stakeholder projects can be undertaken more successfully. Although his paper chimes with, and modestly reinforces, the scant literature in this area its greatest value (I believe) is in the closing few lines; gems of advice for future architectural professors who want to exploit the benefits of stakeholder involvement while avoiding the potential pit-falls.

Although Robert and I were jointly responsible for the seminal idea as well as the structure of the paper and the research methodology, he undertook the data collection and primary writing responsibility on his own, working diligently and enthusiastically over the best part of two semesters. He gathered his interview data professionally and efficiently, and his writing was concise and well-structured. Within our small department, Robert has made a not insignificant contribution to our burgeoning undergraduate research culture while guiding the future practice of our faculty. Robert Jackson graduated in 2010 as the School's Senior Scholar – achieving the highest G.P.A. in his peer group. This paper, as well as the numerous accolades gathered during his time with us in Fayetteville, stands as testament to a remarkable young man, who has the potential to be an outstanding professional and a credit to his alma mater.

IN-VIVO TESTING OF VERTICALLY ALIGNED NANOWIRE IMPLANTABLE TITANIUM ELECTRODES IN THE RATTUS NORVEGICUS HIPPOCAMPUS

By Lauren Kegley
Department of Electrical Engineering

Faculty Mentor: Vijay Varadan
Department of Electrical Engineering

Abstract

Miniaturized multielectrode arrays are MEMS devices that have found use as neural prosthetics (Neuro-MEMS). As implants, they can interface with neurons as sensors or actuators and help compensate for loss of sensory input, motor control, or cognitive functions. The microelectrodes studied here were developed in-house. They have a vertically aligned gold nanowire array and are mounted on a sturdy titanium needle with a fine gauge. Hence, the bill of materials and design characteristics encourage their use as a neural probe. For this study, a probe was tested in vivo for signal acquisition in the hippocampus of a Rattus Norvegicus (Sprague Dawley Rat). Using an Institutional Animal Care and Use Committee (IACUC) approved protocol, the neural probe was deployed in the CA1 region of the hippocampus of a sedated rat. The signal was obtained as voltage against time and was filtered for isolated spikes of neural activity, which were sorted in the form of a Spike Train-Raster Plot. The qualitative evaluation of data obtained through the newly developed neural probe was used as groundwork to decide on future research and discuss possible clinical impacts.

Introduction

Neurological disorders and injuries to the central nervous system can have a serious impact on patients and their support group. Neural conditions can cause an individual to lose his or her independence to a spinal cord injury or Parkinson's disease and can be seen in the anguish of a family watching a loved one diminish as a result of Alzheimer's disease. Contemporary medicine uses an electroencephalogram (EEG) as a diagnostic tool for the detection of abnormal neural functions that manifest as the above-mentioned diseases. The EEG technique is based on measurement of the electrical signal that travels through the central nervous system and facilitates communication. In addition, in vivo measurement of neural activity has been widely used among researchers for many years.

Since the experiments conducted by Luigi Galvani (1791) [1] to measure bioelectric forces in living tissue, researchers and practitioners of nerve physiology have been able to acquire and simulate electrical signals that travel through nerve axons. The model proposed by Hodgkin and Huxley in 1952 has often been used [2]. The electrode technology for neural activity measurement has evolved from a glass electrode [3] to a metal electrode [4] and has gone through drastic miniaturization, resulting in microelectrode arrays (MEAs) [5]. The MEA, which can be on a flat substrate or in bundles, allows for multisite recording within the brain tissue on the individual neuron level, which is instrumental for the observation and statistical analysis of region-specific phenomena. In recent years, the MEA system has been reinvented via needle probes with microelectrodes, popularly known as Michigan Electrodes [6] or Utah arrays [7]. Needle probes such as these allow for higher spatial resolution and precision in locating the neural cluster inside the brain.

Currently used implantable neural electrodes were considered a breakthrough in science that allowed doctors to more efficiently treat patients based on the capacity to interface with neurons and provide clinical applications for neural prosthetics. Commercially available neural probes are microwire arrays of flat electrodes mounted on a fine-gauge wire or needle (230-500μm) made of biocompatible metals such as stainless steel and platinum/iridium (Plexton Inc., Dallas, Texas). While these commercially available implantable neural electrodes can effectively monitor brain signals up to individual neuron resolution, further miniaturized nanoengineered neural electrodes can be developed for more accurate sensing of the electrical signals produced by the brain. At the University of Arkansas, such a neural device was created by Yoon and co-workers [8]. Vertically aligned nanowire arrays were grown on the electrodes (<30μm dimension) to enhance performance and functionality, and then the array of electrodes was fabricated on a fine-gauge titanium needle (280x100μm). The uniqueness of this new type of neural probe lies within the materials used to fabricate them; titanium and gold were used to create these flexible and biocompatible electrode array probes. The sturdy fine-gauge titanium probes can provide continuous in vivo monitoring without breaking or having a large impact on the affected organ. This new form of implantable neural probe is also unique because of its implementation of vertically aligned nanowire array technology, which provides a large electrode surface area that improves the sensing capabilities of the whole device despite its smaller size.

The study described here is a preliminary test of this newly developed titanium neural probe in the Rattus Norvegicus (Sprague Dawley laboratory rat) hippocampus. The study was conducted on live (intact) rats to evaluate the efficiency of the probe's signal acquisition and the stereotactic accuracy of the implantation protocol. The hippocampus is the region of the brain that is crucial for the formation of new memory. It acts as a gate for the passage of newly acquired memory – facts, skill sets, or habits – to permanent memory storage. The basic architecture of the hippocampus is a layer of densely packed pyramidal neurons and well-aligned axons originating from them [9]. Since the axons

are the carriers of neural electric pulses, a strong electrical signal of defined polarity shall accompany any neural activity. Therefore, this region provides a very good ground for testing the newly developed titanium neural probe for the efficient measurement of bioelectric signals.

Experimental Setup

The animal experiment was conducted in an Institutional Animal Care and Use Committee (IACUC) approved laboratory situated at the Central Laboratory Animal Facility at the University of Arkansas. The laboratory includes a data collection center, a surgical workspace, and an anesthetic unit. The data collection center consists of a computer that is connected to the data acquisition equipment, with a 32-channel differential amplifier system (Multichannel System, Reutlingen, Germany) that processes the gathered information via MC Rack Software [10]. This software allows the data to be filtered and viewed in many different ways, including analog spikes of neural activity or a raster plot of the spike train, depending on the necessary analysis.

The surgical workstation (Fig. 1) includes the animal experiment and multichannel feed to the amplifier. The animal experiment setup has a thermal mat to help maintain the rat's body temperature and a stereotactic frame (Korp Instruments) that consists of a head holder and brace to help immobilize the subject, calipers to help measure the brain coordinates, and a holder for the neural probes deemed necessary for individual experiments. The entire setup is mounted on an optical bench with a Faraday cage that cancels out electrical and acoustic noise from external sources.

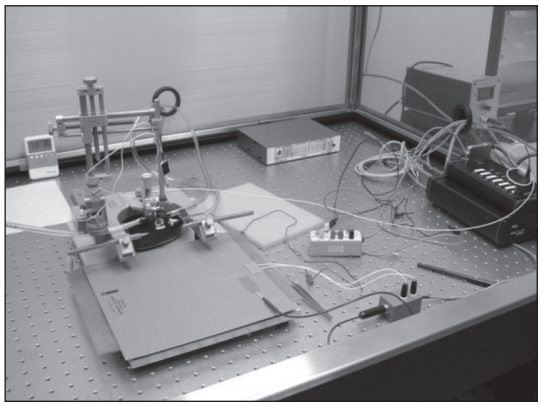

Figure 1. Surgical workstation mounted on an optical bench inside a Faraday cage and equipped with a stereotactic frame.

Once the animal experiments were completed, the collected data were taken to the Brainwave Laboratory at the Engineering Research Center (ENRC) of the University of Arkansas for analysis. This laboratory has a variety of tools to use in data analysis. The collected data were interpreted and conclusions drawn. Since the ENRC also houses the cleanroom (Innovative Nano-Bio Laboratory and HiDEC) facility for fabrication and instrumentation of the titanium neural probes, the lab was also used for experimental preparation and technical changes.

Methodology

The experiment (approved protocol IACUC# 10023) utilized animal subjects of the species Rattus Norvegicus, more commonly known as the Sprague Dawley Rat. The animals were stored in polycarbonate cages with dimensions of 19.5" x 10" x 8" at a population density in compliance with the recommendations listed in the Guide for the Care and Use of Laboratory Animals. Cages were bedded with a 75% aspen chip / 25% cellulose bedding mixture, and rats were fed a standard laboratory rodent diet ad libitum. Tap water was also provided ad libitum. The subjects were split into two separate groups, each containing three Sprague Dawley rats. Group 1 consisted of rats to be tested in the first phase with acute neural recording in the hippocampus, which was done to test the instrumentation of the nanowire probe and to confirm its recordings. Group 2 was earmarked for the second phase, where acute neural recording was done in addition to brain stimulation of mirroring positions in the hippocampus.

Prior to each experiment, the subject was weighed, and an appropriate dose of anesthesia was calculated. The anesthesia method used was intraperitoneal injections of urethane, which was based on a dosage amount of 5.6 ml / kg of body mass. Once calculated, the anesthesia dosage was split into three equal injections that were administered at 2-minute intervals to ensure that the subject would not overdose. Subsequently, the subject was prepared for surgery. Small dosages of anesthesia were set aside and administered subjective to the rat's state of sedation during the course of the procedure. Apart from the anesthesia, no other medication was given to the subject. The neural activity was recorded from the rat in a sedated state, and the animal subject's vital signs were monitored at all times.

The tools and probes were sterilized with a diluted betadine solution to ensure that aseptic techniques were implemented. Prior to sterilization, all the equipment discussed in the experimental setup was checked for appropriate functioning.

Figure 2. Experimental setup of the laboratory settings: Animal subject on the surgical work station with the neural probe (arrow) mounted on a stereotactic frame.

Once the animal was completely sedated, electric shears were used to remove hair on the rat's scalp between the eyes and ears, carefully avoiding the eyes, whiskers, and ears of the rat. The rat was then placed in a prostate position on the thermal mat, and the head was secured by a head holder and a brace. The eyes were

covered, and the areas surrounding the incision area were blanketed with sterilized towels in order to expose only the incision area. The majority of the body remained visible to allow for the detection of stress responses; however, the area directly surrounding the incision area was covered to maintain sterility. Before an incision was made, the shaved area was cleaned with betadine swabs to further sterilize the area. Next, an incision large enough to access the quadrant of interest was made. Post incision, the subdermal layer of blood vessels and tissue was scraped off with hydrogen peroxide swabs so that the bregma and lambda were visible to serve as medial and baseline references (Fig. 2).

The positions (x, y, and z coordinates) of bregma and lambda were recorded with the help of the calipers of the stereotactic platform. The location of the burr hole was determined by referring to a "Rat Brain Atlas" [11], and the burr hole location was marked with the help of a pointer that was also mounted on the caliper platform. A pre-sterilized drill bit was used to make two burr holes: one for the needle probe and the other for a reference electrode placed away from the probe site. During the operation, the subject's eyes were kept moist with phosphate buffer solution (PBS) swabs, and the subject's vital signs, especially breathing, were monitored via observation. Though sufficiently anesthetized, each rat was also observed for any stress responses (twitching, tremors).

The probe and multichannel acquisition system was prepared by tuning the noise filter to filter the raw signal for DC offset and high-frequency noise. This was done on the MC Rack software console by setting the sampling rate of the band pass filter and allocating the channels to be filtered. The signal acquisition was taken at a specific hippocampus site: interaural 5.76 mm, bregma 3.24 mm, and 2.3 mm deep from the dura. Signal acquisition was commensurate, and the filtered signal was simultaneously sorted for spikes. For immediate feedback of the signal acquisition quality, each spike was heard as a pop on the audio speakers. The acquired data bank was then processed as a pulse train, with -160μV as the threshold, to extract raster plots.

Euthanasia was carried out at the end of the surgical procedure, while the subject was still under anesthesia, by CO2 asphyxiation until clinical death (no perceivable signs of respiration) was determined. Upon completion of the animal experiment, all the surgical materials were disposed of or sanitized according to aseptic technique. The data acquired were filtered, and basic analysis, which was simply the organization of collected data, was completed in the experimentation lab. Extensive analysis was carried out in the brainwave laboratory.

Results

After the testing was complete, the analysis procedure was begun; this phase of the research was essential to determine the accuracy and dependability of the neural probe being tested. The neural spike activity was sorted and stacked to better understand the average peak neural activity in one cornu ammonis (CA1) and the horns of the hippocampus (see the inset of Fig. 3 (a)).

The region in question is densely packed with axons originating from the pyramidal neurons in the outermost layer of the hippocampus. The titanium neural probe was able to detect neural

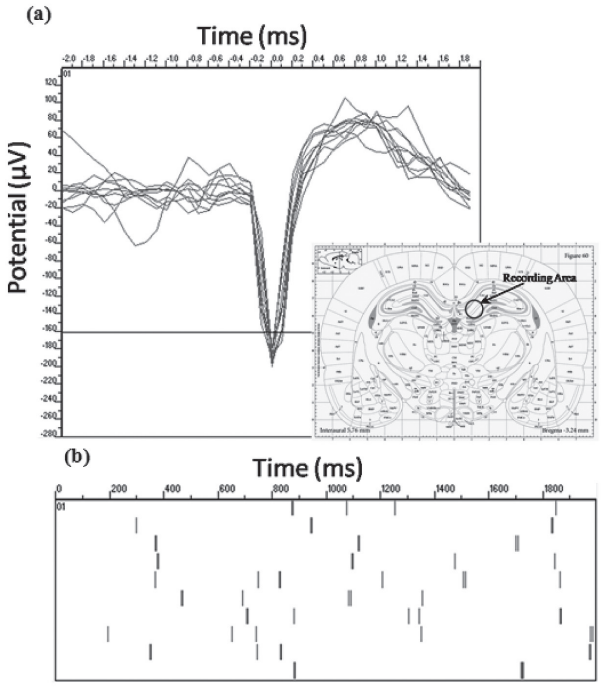

Figure 3. (a) Spikes of neural activity in 4 ms time-amplitude window measured at the CA1 region of the rat hippocampus (b) Spike train Raster Plot with -160 μV threshold.

activity of discernable quality, which can be seen in Fig. 3 (a) and (b).The spikes were sorted based on a pre-specified threshold of -160 μV, and the resultant spike train is represented as a raster plot. The amplitude-time window (Fig. 3 (a)) shows well-isolated potential peaks with a mean amplitude of -180±10 μV. The corresponding spike train (raster plot) along the timeline can be interpreted based on the firing rate of the neuron(s) or the statistical analysis of these spikes/epochs surrounding a documented event (for example, a motor or sensory response to external stimuli) [12].

Discussion

The database acquired from the animal experiment can be filtered and re-plotted for further analysis. Signal processing and analysis facilitates interpretation of data depending on the clinical relevancy of the information. Potential applications of this analysis are provided in the following sections.

Spike train analysis

The spike train from the neuronal ensemble (bundles) can provide control signals for limb movement, represent sensory inputs, or be translated as a highly evolved cognitive signal [12]. The spike train can be represented in the form of spike raster plots (Fig. 3 (b)) that provide information such as spike frequency and spike epoch (width of the raster). This can be treated as a discrete transform of continuous waveforms, which can be characterized on the basis of the functionality of the region of the recording site. For instance, in the hippocampus, spike trains observed in the CA3 and CA1 regions can be respectively categorized as inputs and outputs of the hippocampal memory formulation process [13]. The analysis of such signals can be achieved with covariance/correlation studies between variables or parametric estimation.

Clinical impact

The study detailed in this article focuses on recording neural activity in the pyramidal neuron and axon bundle of the hippocampus. Further experiments shall be able to show that multielectrode needle probes can also be used for measuring (extracellular) field potential (FP) and fiber volley in other neuron bundles; such an ensemble of signals can be analyzed and translated as intended actions or wanted sensory inputs. The evaluation of the titanium needle probe, through animal experiments, will be helpful in accessing the probe's capabilities in various medical applications that employ neuro-MEMS interfaces. These needle probes can be passive or active components that serve as sensors or actuators for technologies such as a neuromotor prosthesis or a prosthesis to replace or restore local neural functions. A fully tested multielectrode probe system has an additional application in neural interfacing for prosthetic limbs [14] to successfully emulate intended movement, controlling other external electronic gadgets for persons with disabilities [12,15], or even for multi-taskers, cochlear implants for the hearing impaired [16], and futuristic applications such as artificial retinas [17] and speech synthesis technology [18]. In the field of neurobiology,a study of neural conditions, such as Parkinson's disease [8,19], Alzheimer's disease [20],and Traumatic Brain Injury [21], involves capturing the spatio-temporal neural activities [13] and then using these multielectrode needle probes, via a sensor or actuator, as an investigative tool and therapeutic aid.

Future research and conclusions

The reported study is a work in progress. Demonstration of quality measurement of neural activity, with the help of vertically aligned nanowire array equipped electrodes on a titanium needle probe, is a precursor to specialized neuro-MEMS interface studies. A recording of neural signals through multiple electrodes should be attempted to analyze the probe's capability to detect activity of a neural ensemble for comprehensive monitoring of functionality. The results of these experiments should be compared with those obtained for commercially available electrodes such as those supplied by Plexon, Inc. (Dallas, Texas). The results of this study shall be instrumental in advancing needle probe applications in neuroprostheses and investigations of pathological neurophysiology.

Evaluation and instrumentation of nano-structured multielectrode array neural probes are important for the development of more advanced technology for the accurate measurement of neural activity. Since the multielectrode arrays are mounted on a sturdy titanium needle with a fine bore, they can be considered implantable devices. Implantable neural probes / electrode arrays that are interfaced with neuron bundles / clusters try to harness the signal strength of the human brain and correct problems internally; such electrodes have been used to treat Parkinson's disease through deep brain stimulation. Extensions of this implantable technology are expected to play important roles in the treatment or management of other neurological disorders. This progressive technology will not only make it possible to improve the lives of many through simple surgeries but will also make it possible to build upon this technology in order to create other life-altering cures.

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Mentor Comments: Professor Varadan describes the commitment of Lauren Kegley to her chosen research domain in the neurosciences.

Lauren is an undergraduate student in the field of Electrical Engineering; she has spent the past two years working on research projects under my supervision and continues to pursue her neuro-scientific research on acquiring pulse trains of neural activity from rat hippocampus. The motivation behind her work is her interest in engineering related medical technologies. It has led her to participate in and carry out research focused on implantable prostheses for monitoring bioelectronic neural activity. This publication showcases her work on a project in which she performed data acquisition, surgical procedure, and final analysis with the supervision and training of two Doctorial candidates, in addition to myself. This translational research shall help in advancement of neural prosthesis technology in the medical field. It will allow neurological disorders, like Parkinson's and Alzheimer's to be treated more effectively. Thus, the project that she has undertaken is a pioneering one. In addition to this publication, Lauren has received a Summer Undergraduate Research Fellowship (SURF) grant and recognition at the NSF Annual Conference for the best poster of an undergraduate researcher. Lauren is a very promising young researcher from whom great things can be expected. As her mentor, I truly believe that she is a very dedicated, hardworking, and inquisitive student.

BEYOND THE PIE: COMMUNICATING WITH SMART OBJECTS USING MENU-BASED NATURAL LANGUAGE INTERFACES

By Tanmaya Kumar

Department of Computer Science and Computer Engineering

Faculty Mentor: Craig Thompson

Department of Computer Science and Computer Engineering

Abstract

In both real and 3D virtual worlds, people and avatars (representations of people) need to be able to communicate with things around them. Without guidance, however, people cannot use the language that the things can understand. The goal of our research is to extend the 3D virtual world Second Life® to better model pervasive computing and overcome the boundaries of communication. The aim of this paper is to show how to build a dynamic menu-based user interface that enables humans to communicate with model entities. The focus is the applicability of object-specific grammars associated with things (objects in the real and virtual worlds) and a GUI consisting of cascaded menus to guide people in "talking to" things. This paper discusses the prototype model of a new virtual controller that takes us closer to the ultimate goal – a system that extends the Second Life user interface so that people can task robots using a menu interface

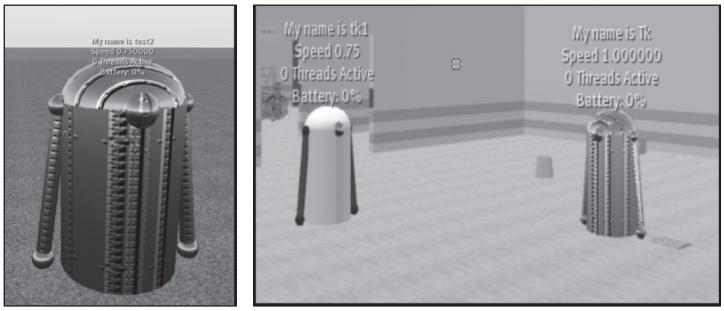

Figure 1. The bots on University of Arkansas Island in Second Life, a 3D Virtual World.

Context

This report is associated with the "Everything is Alive" project at the University of Arkansas, which is exploring pervasive computing both in real-world RFID applications [1] and in virtual worlds, especially Second Life [2] and Open Simulator.

Problem

People use natural languages to talk to other people. Researchers have been trying to develop natural language interfaces (NLIs) to talk to databases, for example, for the past 40 years, but success has been limited. It is currently difficult to impossible for people to communicate and converse using NLI with most non-human things around them (e.g., chairs, thermostats, pets, blood pressure machines, and forklifts). A recognized reason is the habitability problem [1]: humans overshoot and also undershoot a system's ability to understand human language. Overshooting means that people use language that the system fails to comprehend, so the system is unable to respond to the command appropriately. Undershooting means that people make the system execute very trivial tasks and do not realize the capabilities of the system, thus failing to use many powerful features of the system.

Another major issue with objects around us is that they do not explicitly know their own identity or type. The concept of ontologies is absent ("I am a unique chair"), and the objects have no way to associate additional information with themselves (*"I am owned by Tanmaya"* or *"I am a light switch that has been turned on 313 times this year"*).

People do not simply want a way to talk to real-world objects. In virtual worlds, in-world objects may have associated information and scripts, but the ability to extract the information or manipulate the object may rest solely in the head of the object developer. No avatar passing by can learn the command language of the object and interact with it. To aid the user, Second Life offers the PIE user interface, which a user can access by selecting an object and giving generic commands such as *sit, take, copy,* and *buy*. However, none of these commands are object specific, nor do they allow the user to manipulate the special capabilities the object may have. For example, thermostats do not have their own object type specific commands.

Objective

The aim of this research was to enable human-object interaction in both real and virtual worlds by providing a GUI interface that can be parameterized by the physical properties of everyday objects. In the initial implementation, interactions were limited to one type of entity. In the Second Life 3D virtual world, robots with command language modules are available, so the form-based natural language interface was tested by commanding and querying the robots.

As mentioned above, Second Life currently employs a pie-shaped interface that allows the user to select from a "fixed and limited" array of generic verbs that allows the avatar to perform very basic actions such as sitting and touching objects. Even though the pie can cascade to give a small number of additional commands, the pie commands are not object-specific. What is needed is a way to extend this user interface to communicate with things in a thing-specific language. In the current work, the target is the Second Life robots on the University Island.

Approach

A series of Form Based Graphical User Interfaces (GUI's) was used which provides a common way for humans to communicate with computer-based objects. A complementary alternative is Menu Based Natural Language Interfaces (MBNLI'S), which provide sequential command completion menus [3] similar to drop-down menus. Both alternatives provide a way to solve the habitability problem since both provide a way to display all and only the legal commands a system can handle. Instead of "creating" an unsupported query, as is done in conventional NLI, by using GUI or MBNLI, human users can "recognize" the command they mean to formulate while creating an appropriate string of commands with a command builder. This method also enables humans to see commands that they might not have known about. That is, humans are guided to rendezvous with the capabilities of the system, thus eliminating the chance of a user undershooting or overshooting a system's capabilities.

Progress

We developed a prototype next-generation PIE interface for Second Life that uses a combination MBNLI-GUI to enable humans to communicate with specific things. In our initial implementation, we limited interactions to one type of entity: robots [5]. A student at University of Arkansas, Nick Farrer, had previously developed a Robot Assembly Language that provided chat-based commands in Second Life to control a fleet of robots that can go from location to location following way points and can pick up, carry, and put down objects.

In order to get a PIE that operated in both Second Life and OpenSim, we developed our PIE code outside both environments so that it could overlay as an external application on top of those browser-clients. We developed object-specific grammars such as the one shown below for robots. If the user clicks on a robot, the grammar commands for the robot are interpreted and displayed in a cascade on the menu. At the end of a PIE command sequence such as "Robot – Pickup – the ball", the command is translated into a command in the Robot Command Language, transmitted over to the robot in second life via an HTTP callback, and then executed.

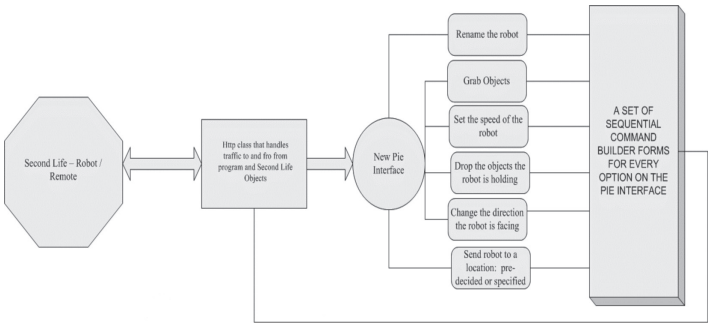

Figure 2. The program design and interaction paradigm. The change from one pie to another is seamless, as the new pie has been integrated into a small script that corresponds to the main program running on a stand-alone system via an HTTP callback and is activated by a single left mouse click on the object the avatar is interested in. The new Dynamic PIE 2.0 is shown below against the pie menu provided by Second Life®.

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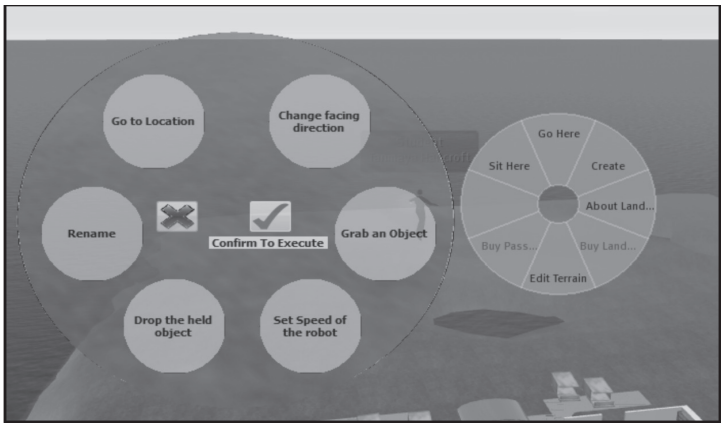

Figure 3. The new pie interface (left) [2] vs. the one provided by Second Life (right).

Implementation and Hurdles

The primary aim of the project was to develop an interface to facilitate the interaction. The interface was built entirely outside Second Life® using Visual C#. It interfaces with objects inside Second Life® using an HTTP callback class which ferries commands and requests to and from the target object: in this case, the robots and the soft controller/transmitter on the avatar's hand. The stand-alone nature of the PIE 2.0 is not accidental; it was developed as a plug-in to Second Life®, OpenSim, and all supported virtual worlds to support extreme portability and to avoid the legal software licensing issues afflicting Second Life and Open Simulator. [6]

Sample Command Building Process

The new pie interface works by using a pre-programmed set of forms as interfaces for the command development. Normally, the bots function by listening on the common chat channel, "Channel 0," for commands being issued to them by the user (avatar). The commands are all typeset and are hard to memorize, formulate, and reproduce at the desired instant. The following is a sample workflow for a worker robot collecting a clock from a shelf and moving it to the loading dock

1) SampleBot rename to MyBot (Renames robot to MyBot)
2) MyBot wp shelf2 (Sends robot to waypoint named shelf2)
3) MyBot grab nearest Clock (Grab clock from the shelf)
4) MyBot wp loading (Sends robot to loading dock)
5) MyBot drop (Robot drops clock at the loading dock)

The following figure shows how some of these commands can be built in the new interface without having to have these command steps memorized.

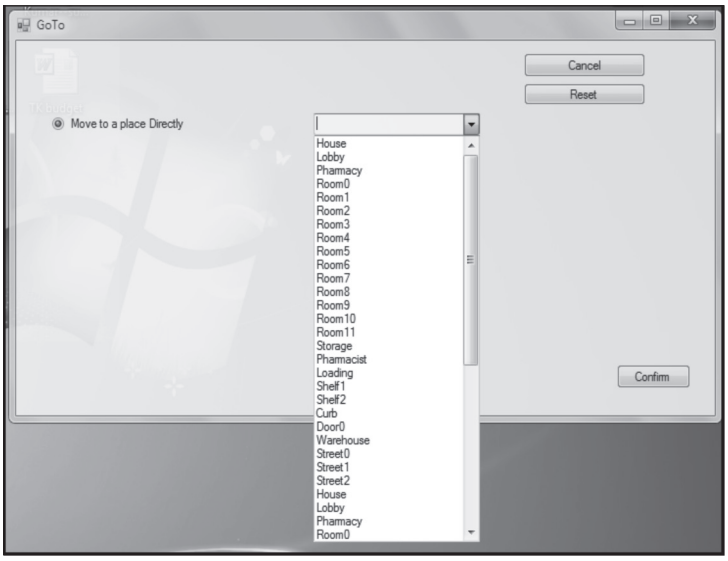

Figure 4. An instance of the Go to Location Command builder and list of way-points.

Future Work

The ability of humans to communicate with things is a significant step towards a smart world (e.g., smart homes, smart buildings, and smart hospitals) where many or all objects are network objects with an identity and the ability to communicate (wired or wirelessly) with other objects or with humans. The results of the current research enhance our understanding of the working of the Second Life PIE in detail. It was a prototype hardcoded to control the Robots on "University of Arkansas" island in Second Life. Even then, the interface did not cover all of the command language. Most other Second Life objects still lack the ability to understand their own type and any super- and sub-classes, which indicates another place to begin. In addition, the grammars are not yet dynamically loaded into the PIE. While there is considerable work ahead, a set of problems to solve has been isolated.

Some requirements for future work will include the development of objects that can identify themselves as belonging to a parent class, such as a chair knowing it is a type of furniture. In addition, there is a need for an API that recognizes the type of object and recalls the particular set of grammar rules that apply to the object, possibly even differentiating the availability of grammar rules on basis of the user. Last but not the least, it is necessary to include the concept of object-specific grammars and the need for developing grammars for every kind of real-world thing. More specifically, the following goals need to be achieved:

1) Consider other Second Life objects such as the objects of a smart home. If grammars can be developed for everything and put in a remote cloud to be accessible to the users, and if the users can download them on their smart phones, the boundary of communication between a people and their surroundings can be breached. Users can then, in a simple sense, talk to anything around them wherever they are. (Fig. 6)
2) Build a more advanced interface that can handle complex commands using a grammar-based control structure, complex translations, and ontology structures. (Fig. 7)

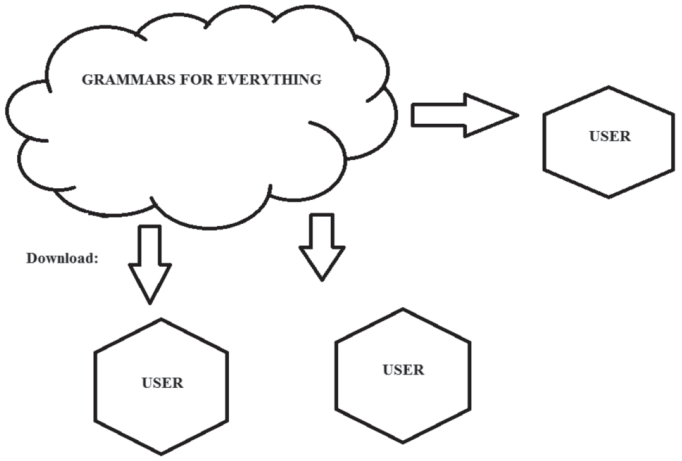

Figure 6. The grammar cloud concept

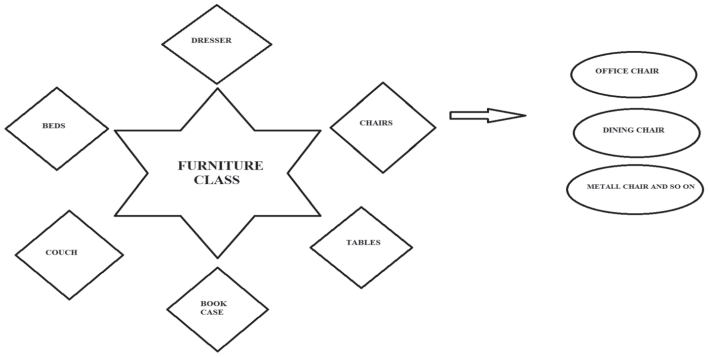

Figure 7. Ontology Architecture

3) Develop role-based interfaces such as those specific to a particular task (e.g., a wood-cutting machine for a car penter or automotive tools for a mechanic).
4) Develop mechanisms to control and limit access by users by differentiating authorized and unauthorized access or by attaching an inventory of objects to a particular avatar so only that avatar can access them. This feature is similar to the act of owning and commanding objects in one's own home.

Finally, if smart grammars work in Second Life, they can be made to work in the real world. If every real-world object has an RFID tag that identifies it and if every smart phone can read RFID tags (which will happen when RFID becomes a consumer-level technology), then consumers can shop or walk around and use their smart phone to communicate with things around them (e.g., canned goods, the thermostat, their cat) using technology similar to the technology being designed.

Potential Impact

If we can determine the kinds of interfaces an object can possess, develop a synthetic grammar for the commands and replies for the object, and extend the communication interface to support interaction, it will make it possible for humans to interact with objects. A similar approach can be used for people using soft controllers (smart phones) to communicate with everyday objects

in the real world. If every real world object has an RFID tag that indicates the object's individual ID, a smart phone with an RFID reader can communicate this information to a remote ontology on the web to download an interface that will let a consumer talk to the thing. If it becomes a standard (optional) protocol to define such interfaces for all things, then anyone anywhere can communicate with any tagged thing.

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Mentor Comments: Craig Thompson points out that, unlike many freshmen, Tanmaya Kumar began his studies at the U of A with a clear commitment to the investigation of artificial intelligence. As a result, he has been very productive in his time here.

From the beginning of his freshman year in Fall 2008, Tanmaya knew he wanted to major in Computer Science and do research in the area of artificial intelligence. Funded by two UA Honors College Undergraduate Research Grants, he joined my Everything is Alive (EiA) research project which is focused on pervasive computing. Tanmaya was particularly interested in how humans can communicate with real world things. The thesis is that in the smart world of the future, every object will have identity, the ability to communicate with other objects – and we need a way so that people can communicate with objects to command and query them. Tanmaya built on my earlier research on menu-based natural language interfaces that guide a human so they know what domain restricted language they can use to talk to a specific kind of thing. Furthermore, he observed that the Second Life user interface (a menu in the shape of a pie that provides a user choices when they click on an object) is extremely limited and generic. He decided to extend the Second Life pie menu so the user could provide their own object-specific commands. He demonstrated his new pie interface tasking robots with commands like – Robot, pick up the book and take it to the library. His work is valuable not only in the virtual world but can also be applied directly to real world objects. If we attach RFID tags to real objects and add RFID readers to cell phones, we will be able to upload user interfaces to cell phones so humans can use these smart phones as truly universal remotes to communicate with tagged things around them. To document his work, Tanmaya wrote the paper ""Beyond the Pie: Communicating with Smart Objects using Menu-Based Natural Language Interfaces"" for the X10 Workshop on Extensible Virtual Worlds (http://vw.ddns.uark.edu/X10, March 29-30, 2010). During the summer 2010, Tanmaya is extending his initial work into a project we are calling "My Immortal Avatar" (http://vw.ddns.uark.edu/X10/content/APPLICATION--My-Immortal-Avatar--Kumar-Thompson.pdf¬) which aims at using an avatar chatbot to model an individual human's looks and memories - a new biography genre

MULTIMEDIA AND ULTRAFILTRATION FOR REVERSE OSMOSIS PRETREATMENT ABOARD NAVAL VESSELS

By Angela C. Mehner

Department of Chemical Engineering

Faculty Mentor: W. Roy Penney

Department of Chemical Engineering

Abstract

The US Navy is interested in improving the pretreatment for shipboard Reverse Osmosis potable water systems. To investigate this problem, the Navy prepared a Task for the 2010 WERC (http://www.werc.net) competition. The research described in this paper was performed to compete in this WERC Task and ultimately received a 1st place award. Several technologies were considered as options for improving the current pretreatment process. Multimedia filtration followed by ultrafiltration was chosen as the most economical solution. This paper presents the final design for a full-scale shipboard system that incorporates multimedia filtration and ultrafiltration yet requires minimal space and optimal power usage. Although the work focuses on oceanic applications, inland water desalination plants can economically use the technology. The proposed process provides an annual incremental savings, including reduced maintenance and filter usage, of $17,000 over the current process, resulting in a payback period of 14 years. However, as savings are highly dependent on the replacement frequency of all components, ships operating in coastal waters may realize greater savings of up to $47,000 annually, thus reducing the payback period to 5 years.

Introduction

Production of fresh water at sea poses a significant problem for oceangoing vessels. In the past 30 years, reverse osmosis (RO) has replaced distillation as the preferred means of large-scale potable water production on ships. Since 1988, RO desalination systems have been used by the United States Navy for the production of potable water. The Navy Standard Reverse Osmosis (NSRO) plant is the standard for these systems, and by 2009, 268 NSRO plants had been installed aboard US Navy ships.[1] In NSRO plants, seawater first enters a centrifugal separator (hydroclone style) which removes approximately 95% of particles over 50 μm.[2] Smaller particulates are removed by a series of cartridge filters (20 μm followed by 3 μm), and the pretreated water is then desalinated using spiral-wound RO membranes. In open waters, the cartridge filters can last 4-6 weeks before requiring replacement, and RO elements last for 3-5 years.1 However, in littoral and coastal waters, which are characterized by increased levels of suspended solids, RO membranes can fail in just a few months, and cartridge filters often last less than 10 hours. Therefore, advanced pretreatment technology is needed to reduce maintenance time and decrease storage area requirements while also providing a higher quality feed to the RO unit. High-quality feed water is commonly defined as having a silt density index (SDI) of less than 3 and a turbidity of less than 1 NTU (nephelometric turbidity unit).[2]

To encourage improvements in the pretreatment of shipboard Reverse Osmosis potable water systems, the U.S. Navy prepared the Task for the 2010 WERC (http://www.werc.net) competition. The problem statement in this task was, *"Develop and demonstrate an alternative to disposable filters or an improved disposable filter design that can last at least four months filtering somewhat turbid feed water. To increase the life of the RO membranes, ideally your proposed process will address particle size down to 0.1 microns as there are suspended solids that do pass through the current cartridge filters and foul the RO membranes."* This paper describes the research of a team of chemical engineering students who responded to the 2010 WERC Task. The team's design premises for the WERC Task were as follows:

1. All particulates above 0.1 microns are to be removed.
2. Energy usage must be less than 10% of that used for the RO system.

   Note: The calculated RO system energy requirement is 12 HP, with an energy recovery device that is 50% efficient (from ROPRO software with RO recovery of 40%).
3. 30,000 gal/day of filtered seawater is to be supplied to the RO system.
4. The operating unit should occupy no more than 300 ft^3 (3 times current cartridge system).
5. The system should be green (i.e., chemical discharge is mini mized).
6. Maintenance time must be less than that for the current system (4 hours every 4 days).
7. Storage space for a 9-month time frame must be less than 100 ft^3 (1/10 of current system).
8. The system must be designed to handle a feed of the follow ing composition:
   A. 32,000 ppm of sea salt
   B. 75 mg/L of Klamath Blue-Green Algae powder
   C. 20 mg/L of Orchid Pro (by Turf Pro USA), an orchid fertilizer liquid product
   D. Dechlorinated tap water

A survey of the literature was conducted to identify many variations of filtering technologies which could be used to remove particles down to 0.1 μm. However, like RO membranes, most fil-

ters are prone to fouling under turbid feed conditions. Prefiltration for these modules is required because subjecting a membrane to biological colloids increases the rate at which the transmembrane pressure increases.[3] Therefore, applicable filtration technologies were broken into two categories: (1) prefiltration and (2) micro- or ultrafiltration.

Prefiltration, for the purposes of this report, refers to technologies which remove particles down to 1 μm. Technologies considered to replace the current cartridge depth filters included centrifugal separators as well as coagulation, electrocoagulation, and media filters.

Hydroclones, such as the centrifugal separators currently in use by the US Navy, can separate 50 μm particles with a specific gravity of 1.5 or greater. Hydroclones were rejected because they can only remove particles down to 50 μm and increased solids concentrations in ultrafiltration membrane feeds lead to a decrease in permeate flux.[3]

Chemical coagulation, or flocculation, is the dominant pretreatment for municipal water systems. Chemicals such as ferric chloride and ferric sulfate are added to the feed water to eliminate charges causing mutual repulsion between small particles. Moderate agitation then causes particles to flocculate. The flocs are separated by gravity or filtration. Chemical coagulation was rejected for the task solution due to disposal considerations for the sludge resulting from separating the flocs.

Electrocoagulation, where an electric potential applied between two electrodes causes floccing, has some advantages over traditional methods. Chemicals are not required; thus, their disposal and storage are not issues. Testing has shown that this method has better removal of some species than chemical coagulation.[4] The salt concentration in seawater reduces the voltage requirement; however, energy requirements for electrocoagulation will far exceed those allowed by the premises of this task.

Single-media filters consist of a thin bed of granular material, commonly sand or diatomaceous earth. The filtered particles are trapped in the first few inches of the bed, and water and smaller particles pass through the bed. As the bed is loaded with filtered solids, the bed pressure drop will increase to an uneconomical level, requiring backwashing for regeneration. Single-media filters perform well for a narrow particle size distribution but are not efficient for this system, which involves contaminants ranging in size from 0.1 to 500 μm.

Multimedia filters use layers of different media to trap particles in all active layers of the bed. The media are arranged with the largest and least dense particles on top and the smallest, most dense particles on bottom, supported by an inactive layer of larger gravel. This arrangement allows for solids loading throughout the bed. After backwashing, the variation in media densities and sizes results in the bed's settling into its original layers. Additionally, the high total surface area of multimedia filters removes a greater number of particles and produces a higher quality filtrate.[6] Multimedia filters do not function by simply capturing particles in the voids between media particles but instead attract particulates to the surfaces of media particles by diffusion, sedimentation, and interception.[5] Depending on the media used, multimedia filters will remove particulates down to 5-10 μm. Typical flux rates for multimedia filters are between 5 and 14 gpm/ft2 of the bed cross-sectional area.[6]

Thus, multimedia filtration was selected as the prefiltration step because it is the most economical when considering capital, energy, maintenance, and space requirements. Its high throughput and long lifetime are also advantages. Through backwashing, the performance of multimedia filters can be recovered completely after an increase in trans-filter pressure during a filtration cycle. Additionally, the media has a lifetime of several years, and replacement storage onboard is unnecessary. The media selected were anthracite coal, sand, and garnet, supported by a bed of gravel. This filter will remove particulates down to 10-20μm.[7]

In order to protect the RO membrane and filter to the 0.1 μm level prescribed in the Task problem statement, microfiltration or ultrafiltration was needed. This was accomplished by using membranes constructed of either polymeric or ceramic materials. Advantages of ceramic membranes include the ability to withstand high temperatures and pressures and all pH values. However, desalination operations operate at low temperatures and pressures and almost neutral pH values, precluding the need for thermally and chemically robust ceramics. Moreover, there are several significant disadvantages of ceramic membranes with respect to shipboard water treatment. Although the flux rate through ceramic membranes is high, about 100 GFD (gal/ft2/day), the footprint needed for the surface area is far too large to include onboard a ship as the channel diameters are limited to about 1 cm. Ceramic membranes are heavy and expensive, though the high initial cost is compensated for by a long lifespan.[8]

Membranes are also made from a variety of natural and synthetic polymers formed into several different shapes, including flat sheets, tubes, and hollow fibers, depending on the properties of the polymer. These are then grouped into modules: the fibers and tubes are connected in bundles, and the flat sheets are wrapped into a spiral or left flat.

Flat sheets of membranes may be arranged into a plate and frame module in which the membranes are supported by plates which channel the feed, permeate, and concentrate. Flat sheets can also be used in a stacked disk design. The flow path takes the feed stream along the flat membranes. Flat membranes were rejected based on the system volume requirement.

Spiral-wound membranes offer a relatively large surface area for the volume required. This is the configuration of the RO membranes currently used aboard naval vessels. Backflushing of spiral-wound modules is not an option as the pressure would separate the layers of the membrane and destroy it.

Tubular modules, with tube diameters in the range of 5-15 mm, are fed on the tube side, allowing permeate to pass through the membrane forming the walls of the tubes. Hollow fibers function in the same manner but have smaller inner diameters, from 0.5-1.2 mm, and thus a much smaller volume for a given membrane surface area. Feed flow can be on either the tube or the shell side, which allows the modules to be backflushed to remove foulants. Tube-side flow is most advantageous as it allows a greater portion of the flow entering the unit to flow uniformly over the

membrane surface.

Of the various configurations of UF membrane modules, hollow fiber units were selected because they can be backflushed and provide high flux rates and a large membrane surface area per unit module volume. Although microfiltration is capable of filtering to 0.1 µm, an ultrafiltration (UF) module which filters to a 50 kDa MWCO (molecular weight cutoff) (equivalent to ~ 0.005 µm) was selected instead. The smaller pores will be less susceptible to plugging, making cleaning easier and increasing membrane life.[9] This enhanced filtration will also further protect the downstream RO membrane from fouling and increase its service time.

Finally, several naval and recreational vessels utilize RO units with an open-channel design between stacked discs of membranes instead of spiral-wound modules. This design minimizes pretreatment requirements by decreasing the tendency of particles to become trapped on the surface of the RO membranes. Typical pretreatment for these modules requires only cartridge or sand filters to reduce the SDI (SDI 5) of RO feed water to 15-20. Manufacturers report membrane service times of up to 5 years.[10] Open-channel modules appear attractive for extending RO membrane run times and should be considered for new or replacement RO units; however, the existing RO units need improved feed filtration for longer service times and improved performance.

Bench Scale Apparatus

The multimedia filtration system consists of a feed tank, feed pump, backwashable multimedia filter, and filtrate tank. A photograph of the multimedia filter experimental unit is presented as Figure 1. The flow schematic for the multimedia experimental apparatus is presented as Figure 2. Two multimedia filters were tested. The small filter was constructed of clear 2.445" ID x 5.3' long PVC pipe, and the large filter was constructed of clear 5.625" ID x 4.5' long Plexiglas pipe. Each multimedia filter consists of four layers of media of differing sizes and densities. From the top down, the bed is composed of a 12" layer of anthracite coal (sp. gr. 1.6; d_p = 0.6-2 mm), a 10" layer of sand (sp. gr. 2.5; d_p = 0.6-1 mm), and an 8" layer of garnet (sp. gr. 4; d_p = 0.32-0.39 mm). The lowest bed, which provides support to the upper layers, is a 9" layer of graded pea gravel (sp. gr. 2.65; d_p = 2-5 mm). Filtrate quality is a function of feed quality, retention time in the filter, media characteristics, and bed depth; therefore, the units were designed with the same depths and types of media, and results were compared only at the same fluxes.

The feed, mixed to WERC specifications (32,000 ppm of sea salt, 75 mg/L of Klamath Blue-Green Algae powder, 20 mg/L of Orchid Pro), was fed to the multimedia filter using a variable speed rotary vane pump which delivered 0.08-1.5 gpm at a feed pressure of 25-35 psig. Feed entered at the top of the filter, and increasingly smaller particles were trapped as the feed traveled through the filter, giving effective solids loading throughout the bed. The filter effluent was collected in a 5-gallon pail. During backwash, flow direction was reversed. To start the backwash cycle, the pump was stopped, and the feed hose was moved to the filtrate tank. Flow of filtered water was distributed by the gravel underbed, and the filtration media were fluidized, washing out accumulated sediment. Backwash liquid was drained to a waste tank. Following backwash, normal forward operation was resumed.

Figure 1. Photograph of Multimedia Filter

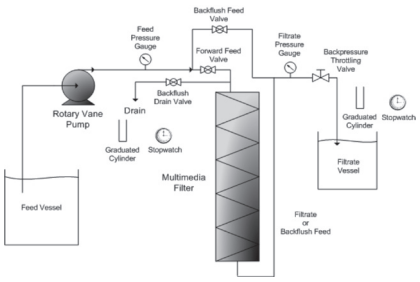

Figure 2. Multimedia Flow Schematic

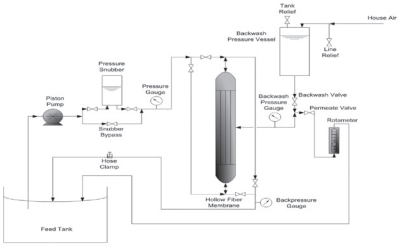

Figure 3. Hollow Fiber Membrane Flow Schematic

The effluent from the multimedia filter was sent to the Ultrafilration Unit, which was a 1 ft^2 hollow fiber UF membrane (Koch HF, 1018-1.0-43-PM50) with a 50 kDa MWCO, as shown in Figure 3. The purpose of this HF unit was to filter particles larger than 0.01 µm from the feed stream by forcing a permeate stream through the tube wall and into the shell side of the module. Permeate exited the module shell-side and flowed through a rotameter to a permeate receiver. The exiting tube-side stream, commonly identified as the concentrate, was recycled back to the feed tank to minimize the amount of feed required for extended tests. A pressure vessel filled with permeate from previous tests was kept at 20 psig using compressed air. During backflushing, a stream of pressurized permeate was delivered to the shell side of the fibers.

A variable speed piston pump delivered feed to the membrane at 25 psig. The feed pump speed and concentrate flow rate were manually controlled to maintain this feed pressure, which fixed the permeate rate for a given level of fouling. The tube-side pressure drop was about 5 psig. The membrane fibers were cleaned by backflushing and reversing the tube-side flow direction. Backflushing and flow reversal occurred every 2-3 minutes to maintain an economically high permeation rate.

The multimedia and HF units were combined into a single automated bench scale apparatus for final experimentation and for the competition. A photograph of this apparatus is displayed in Figure 4. This setup is similar to that of the full-scale design,

where multimedia filtrate flows directly into the HF unit.

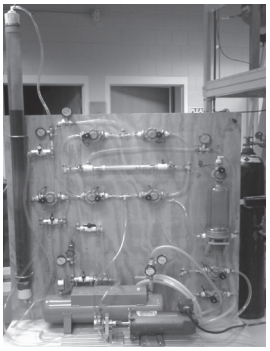

Figure 4. The Entire Experimental Apparatus

Laboratory Experimentation

Laboratory experiments focused on two fronts: (1) determination of the pressure drop, solids loading characteristics, and filtration performance of the multimedia filter; (2) determination of the permeate flux and required backflushing frequency of the HF unit. Conditions were varied to determine the best operating parameters for the pretreatment system.

Multimedia Filter Testing

Multimedia filtration is used as an initial filtration step to minimize UF membrane exposure to foulants. Therefore, successful experiments were those which produced a filtrate that could be processed by the HF system without causing an unreasonable decrease in membrane flux. The fouling potential of the multimedia filtrate was determined by monitoring UF membrane permeation rates over time and by spectroscopic estimation of filtrate quality. Experiments were conducted using both multimedia filters (2.445" ID & 5.625" ID) to determine the filtration rates achievable and the backwash schedules (i.e., the filter solids loading before backwash).

The multimedia filter flux was found by determining flow rates and inlet and outlet pressures for both filters. Flow rate was found to be a linear function of pressure drop across the packed bed, indicating that laminar flow occurred in the bed. Discharge pressure was controlled while the desired feed rate was still obtained. Initial experiments indicated that filtrate quality, as measured by spectroscopic transmittance, was maximized at a flux of 5 gpm/ft^2 of bed area. The filtrate produced using a higher flux of 7 gpm/ft^2 resulted in an additional 19% decrease in membrane flux over 2 hours of operation as compared to the filtrate produced at a flux of 5 gpm/ft^2. Flow rate was kept nearly constant at 5 gpm/ft^2, with a clean filter pressure drop of 4 psig, during subsequent experiments and for design purposes.

The backwash cycle was initiated when the pressure drop across the filter increased by about 10 psig from the clean pressure drop of 4 – 7.5 psig. Figure 5 presents data of the multimedia filter pressure drop over time during filtering of the WERC-specified feed. The multimedia filter was backwashed after 7 hours of continuous operation. Backwashing was performed at a flow rate of 15 gpm/ft^2 of filter bed area to fully fluidize the bed. Following backwashing, as indicated by Figure 5, the pressure drop across the filter returned to its original value. Spectroscopic testing showed that filtrate quality remained consistent before and after backwashing.

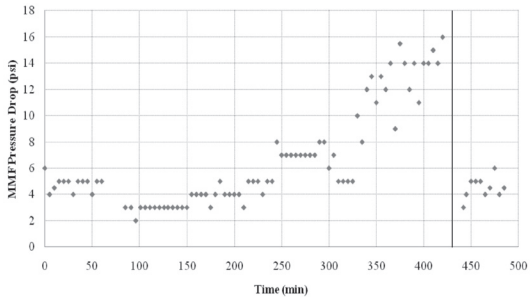

Figure 5. Multimedia Filter Pressure Drop With Backwash Results

Hollow Fiber Membrane Testing

Testing of the hollow fiber membrane was driven by the need to determine operating and cleaning procedures that would allow effective, economical, and long-term use of the membrane, with minimal maintenance time and required replacements. Additionally, chemical cleaning was minimized to design a green system with little onboard chemical storage. Several feed solutions were tested to determine the robustness of the system.

Tests were performed to determine permeation rates and backflush requirements. During these tests, permeate and concentrate flow rates were monitored, as were feed pressure and backpressure. System design and operational procedures were varied to maximize membrane life. A flow-reversal system, requiring only the closing and opening of a few valves, was installed to remove sediment deposits on the membrane surface. Reversing flow direction through the tubes during filtration minimizes the creation of static boundary layers inside the membrane fibers, which readily trap foulants. Additionally, permeate was used to backflush the membrane, removing foulants from the pores of the UF membrane. The membrane was backflushed at predetermined intervals by stopping the feed pump and forcing the permeate to flow backwards through the membrane. Backflushing significantly reduced the rate of permeate flow decrease and resulted in a higher steady-state permeate flow.

Backflush timing and duration were varied extensively during module testing. Testing showed that reducing the time between backflushes yielded greater improvement of steady-state flux than did increasing backflush time, which had only marginal short-term benefits. For the specified feed (after multimedia filtration), stable operation at 22 GFD was achieved after 4 hours of operation with alternating 2 minutes of forward operation with a 30 second backflush cycle, as shown in Figure 6.

A second, more concentrated, feed solution containing 20 mg/L of solids from the Orchid Pro was also tested. Under the same operating parameters, the permeate flow decreased at a faster rate, reaching 30 GFD in only 1 hour.

Membrane Cleaning

During laboratory testing, the membrane was chemically cleaned after each run. The cleaning procedure entailed circulating a 120 °F, 2 L 200 ppm solution of bleach or 1wt% solution of

sodium hydroxide through the membrane for 15 minutes. This was followed by two separate 2 L washes with deionized (DI) water, each of which circulated through the membrane for 15 minutes. This ensured that the bleach was removed from the system. After cleaning, the flux through the membrane was measured with DI water to verify cleaning. This chemical cleaning restored the DI water flux through the membrane to about 150 GFD each of the 10 times it was cleaned. Cleaning with a room temperature 200 ppm bleach solution did not restore membrane flux to the same level; thus, it was essential to heat the cleaning solution to 120 °F.

The feed, multimedia filtrate, and HF permeate were tested for total suspended solids (TSS) and turbidity according to EPA Methods 160.2[11] and 180.1[12] by the Arkansas Water Quality Laboratory of the University of Arkansas at Fayetteville. Results are presented in Table 1. TSS was chosen instead of SDI because the procedure for SDI requires filtering through a 0.45 µm filter disc,

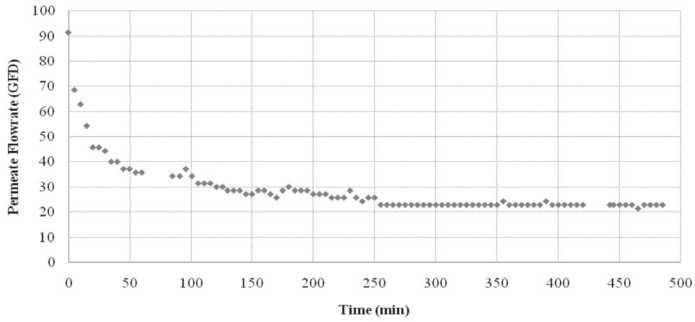

Figure 6. Hollow Fiber Permeate Fouling and Backflush Results

which would result in a measurement of zero as the UF membrane filters to a much smaller level. The multimedia filter reduced the suspended solids by nearly 80% and the turbidity by 70%. The permeate from the HF unit had a higher than expected TSS; however, due to the salt in the sample, it is likely that the results were high because careful experimental procedures are required to wash the filter paper free of salt. Additionally, contamination in the permeate backflush tank was detected after this testing was completed. The permeate turbidity was 1.1 NTUs for this sample, much higher than expected from a UF membrane (< 0.2 NTU). This result may be attributed to the contamination described above and to the use of a bench-top turbidity meter, which does not give very accurate results; in industry, flow-through turbidity meters are standard.

Full-Scale Design

The equipment for the full-scale system consists of (1) a rotary vane feed pump, (2) a bank of 5 backwashable multimedia filters, (3) an array of 4 hollow fiber UF membranes, (4) a membrane cleaning pump, (5) a bleach metering tank, and (6) an inline heater. The pretreatment system is integrated with the RO waste streams to minimize power and water requirements. The full process flow diagram in the Appendix shows the complete system, with multiple units in parallel. The stream attributes, including all flows and pressures, are given in Table 2 for a single-unit.

Seawater is pumped to the multimedia filters at a rate of 106,000 GPD with a rotary vane pump. The raw seawater feed is pressurized to 45 psig by the feed pump before entering a distribution manifold. The manifold delivers water to 5 multimedia filters, each 24" in diameter and 72" in height. Each multimedia filter is designed to process 15 gpm with a pressure drop of 5-15 psig across the packed bed. In typical operation, 5 of the filters are in operation at any one time to deliver 75 gpm of filtered water. During backwashing (which occurs for about 50 minutes over 8 hours), only 4 will be in forward operation. Any or all of the multimedia filters may be used at any one time.

Filtrate from the multimedia filters, pressurized to at least 25 psig, enters a distribution manifold leading to 4 UF membrane elements housed in a single bank array. The membranes are 72" long by 10.75" in diameter. Each cartridge contains 871 ft2 of

Table 1. TSS and Turbidity Results

	TSS	Turbidity
	(mg/L)	(NTUs)
Feed	197.4	45.7
Filtrate	43	13.5
Permeate	15.5	1.1

polysulfone hollow fibers with a 100 kDa nominal MWCO. The inlet manifold is configured to allow flow reversal on the fiber side of the membranes, minimizing concentration polarization zones, which tend to cause fouling. Membranes are operated at 33% recovery (i.e., 1/3 of the feed permeates the membrane) to ensure high shear flow inside the fibers. In normal operation, two membrane modules in parallel will be online. The other two will either be in cleaning mode or in standby mode. When the feed solids concentration is high, all membranes may be operated. Permeate is produced at a rate of 35,300 GPD, and 30,000 GPD are delivered

Table 2. Stream Attributes Table for Simplified Flow Diagram

				Component Flowrates				
Stream ID		Pressure	Flow Rate	Water	Salt	Algae	Humus	Bleach
No.	Name	psig	GPD	lb/day	lb/day	lb/day	lb/day	lb/day
1	Seawater Feed	0	105750	871129	28155	66.4	0.90	0.00
2	Seawater Feed	45	105750	871129	28155	66.4	0.90	0.00
3	MMF Filtrate	40	105750	871129	28155	33.2	0.86	0.00
4	HF Feed (Forward Op.)	40	105750	871129	28155	33.2	0.86	0.00
5	HF Feed (Reverse Op.)	40	105750	871129	28155	33.2	0.86	0.00
6	HF Concentrate (Reverse Op.)	35	70500	580752	18770	33.2	0.86	0.00
7	HF Concentrate	35	70500	580752	18770	32.9	0.85	0.00
7a	HF Backflush Discharge	0	23190	190045	9361	0.3	0.01	0.00
8	HF Discharge	35	63750	525149	16973	29.7	0.77	0.00
8a	HF Backflush Discharge	0	23190	190045	9361	0.3	0.01	0.00
9	MMF Backwash	35	6750	55604	1797	3.1	0.08	0.00
10	HF Permeate	0	35250	290376	9385	0.0	0.00	0.00
10a	HF Backflush	20	23190	190045	9361	0.0	0.00	0.00
11	HF Permeate	0	35250	290376	9385	0.0	0.00	0.00
12	Recycle to Backflush	0	5250	43248	1398	0.0	0.00	0.00
13	RO Feed	0	30000	247129	7987	0.0	0.00	0.00
14	RO Brine Discharge	20	18000	147289	7987	0.0	0.00	0.00
15	Backflush	20	23250	190536	9385	0.0	0.00	0.00
16	Backflush	20	23190	190045	9361	0.0	0.00	0.00
17	Purge to Cleaning System	20	60	492	24	0.0	0.00	0.00
18	Cleaning System Recirc	35	60.08	492	24	0.0	0.00	0.11
19	Bleach (15%)	0	0.08	0.01	0	0.0	0.00	0.11
20	Cleaning Soultion	35	60.08	492	24	0.0	0.00	0.11
21	Cleaning Solution	35	60.08	492	24	0.0	0.00	0.11
22	Cleaning Solution Discharge	35	60.08	492	24	0.0	0.00	0.11
23	Cleaning Solution Recirculaiton	35	60.08	492	24	0.0	0.00	0.11
24	Cleaning Solution Discharge	35	60.08	492	24	0.0	0.00	0.00
25	MMF Backwash Discharge	5	6750	55604	1797	36.3	0.13	0.00
26	Filter Discharge	20	70500	580752	18770	66.1	0.89	0.00
26a	HF Backflush Discharge	0	23190	190045	9361	0.3	0.01	0.00
27	Total Discharge to Ocean	20	70560	581244	18794	66.1	0.89	0.00

to the RO system. The tube-side pressure drop is about 5 psig. Concentrate from the HF array flows at a rate of 70,500 GPD and is used for backwashing the multimedia filters or is discharged to the sea.

Individual multimedia filters require 35 gpm during a 10-minute backwash. Backwashed sediments are discharged to the ocean (see Stream Attributes, Table 2, for average rates). Based on laboratory experiments, each filter should be backwashed every 8 hours. During backwash, the filter unit is isolated by proper positioning of valves, and the bed is fluidized.

The HF system is also equipped with a backflushing system. In the current NSRO system, the high-pressure RO reject passes through an energy recovery device with an efficiency of ~50%, undergoing a large decrease in pressure. The RO reject stream will be pressure regulated to 20 psig prior to its entering the shell side of the UF membrane. Membrane elements are backflushed every 2 minutes for a duration of 30 seconds, one element at a time. Following backflushing, the direction of flow through the membrane is reversed. Backflush fluid is discharged to the ocean.

The UF membranes require daily cleaning to remove fouling; thus, an automated membrane cleaning system is included. A cleaning cycle consists of circulation with a 120 ºF, 200 ppm sodium hypochlorite solution (prepared by diluting 15% bleach), followed by two wash cycles using RO reject. One membrane is cleaned at a time. To initiate a wash cycle, feed to the membrane is terminated, and the permeate line is closed. The positive displacement cleaning pump draws brine from the RO system to fill the tube side of the fibers. Bleach is then metered into the stream from the bleach storage tank, and the stream is heated to 120 ºF by an inline electric heater. This solution circulates through the membrane for 15 minutes. At the end of this time, 150 g of solid sodium thiosulfate ($Na_2S_2O_3$) is introduced manually into the cleaning solution between the bleach tank and pump intake through a inline venturi. The sodium thiosulfate has a solubility of 79 g/100 mL of water (at 4 ºC), which means that it should readily dissolve. Sodium thiosulfate reacts with bleach to produce sodium chloride, sodium sulfate, and water, all of which may be safely discharged directly to the ocean. The cleaning solution will circulate a further 6 minutes to allow the bleach to be neutralized. Then the solution will be discharged into the ocean. Next, two separate washes are performed with unheated brine from the RO system, each circulating for 15 minutes before discharging to the ocean. A hypochlorite monitoring device, installed in the permeate line, is necessary to ensure that no hypochlorite enters the RO membrane as RO membranes have no tolerance for free chlorine.

The design of the prefiltration system meets all space requirements. The process itself occupies approximately 250 ft^3, which is only 2.5 times larger than the NSRO pretreatment system but filters solids down to 0.1µm. Moreover, the design requires only 25 ft^3 for storage of spare HF membranes, sodium hypochlorite, and sodium thiosulfate over a 9-month time frame, which is only 2.5% of the volume used to store filter cartridges in the NSRO system.

The total power requirement for the system, using a 70% efficient rotary vane pump, is approximately 2.6 hp, which exceeds the WERC task limitation of about 1.2 hp. The task-specified power requirement could have been met by adding more surface area through larger multimedia filters and more HF units or by operating at a higher recovery in the HF units. However, the first solution would exceed the operational space limitation, and the second adjustment would increase membrane fouling, requiring more storage of chemicals and membranes and a higher operating cost for replacements or more frequent cleaning cycles, thus increasing maintenance time and process footprint by necessitating more HF units. As membrane fouling is already high and space limitations are stringent onboard ships, the power requirement was determined to be the most acceptable constraint to exceed. The designed power usage will have a modest impact on the overall power requirement of the typical Naval vessel, which is in excess of 15,000 hp.

Seawater is an electrolyte and can cause galvanic corrosion and crevice corrosion, so the materials used for the process must be selected with care.[13] A copper alloy, 70-30 Cu-Ni, is almost insensitive to stress corrosion, retains its strength well at moderately elevated temperatures, has good cold- and hot-working properties, and is readily weldable.[14] Already incorporated into desalination plants, this alloy provides a viable option for the wetted materials used by the process. However, 254 SMO stainless steel, developed for seawater usage, is also a good choice and is recommended for those portions of the process which come in contact with the bleach cleaning solution. Bleach should be stored in a fiberglass reinforced plastic (FRP) vessel to ensure service life in a highly corrosive environment. The multimedia filters are also constructed from FRP to combat the corrosive nature of seawater. Wetted materials for pumps will all be compatible with handling seawater; FRP and 316L stainless steel are acceptable.

Economic Analysis

The total capital investment for the system was determined by a factored estimate based on the purchased equipment cost.[15] In the interests of space, the detailed economic analysis is not provided here. Spare feed and cleaning pumps are required. The total equipment cost is $47,300. Direct costs include equipment purchases, equipment delivery, equipment installation, instrumentation and controls, piping, and electrical systems. Indirect costs incurred in system installation were also estimated. The total capital investment for the process is $230,000.

An incremental economic analysis comparing annual operating costs of the current reverse osmosis system and the proposed treatment system was performed on the basis of 12,000 GPD potable water production, as shown in Table 3. In this analysis, only those costs which were significantly different between the systems were considered. With the current system, 20 µm and 3 µm cartridge filters are replaced at least every 4 days, requiring 4 hours of maintenance each time, for an average of 365 hours/year of labor. Additionally, the lifetime of the reverse osmosis membranes in littoral waters is short, and it is assumed that elements are replaced every 6 months. In the proposed process, the higher quality of the RO feed stream will allow for longer RO membrane service times, and membranes should not have to be replaced over a 3-year period. Due to the harsh nature of the feed water and strict membrane backflushing and cleaning schedule, the hollow fiber

membrane modules will last at least 18 months. Media for multimedia filters should not require replacement more than once every 5 years, but the cost of replacement media for one of the five filters was included in the comparative economic analysis for completeness.

Maintenance requirements for the system are low because it is automated and requires infrequent component replacement. Monitoring of the system will be comparable to that of the existing system; however, operators will need only 30 minutes per day to add sodium thiosulfate following a cleaning cycle, compared to the 4 hours every 4 days for cartridge filter replacement. Operating labor costs are based on man-hours required for system operation, not on the number of operators. The chemicals and cleaning solution heating needed in the new design are considered. Other power cost differences between the two systems are negligible.

The design will save $17,000 in operating costs over one year, yielding a payback period of 14 years. However, as savings are highly dependent on replacement frequency of all components, ships operating in coastal waters may realize greater savings of up to $47,000 annually, reducing the payback period to 5 years.

Table 3. Annual Operating Cost Comparison

	Basis	Savings
RO Replacements	Manufacturer	$10,000
Cartridge Filter Replacements	Manufacturer	$20,000
Operating Labor	183 hour/year at $25/hour	$5,000
UF Replacements	Manufacturer	-$15,000
Bleach (15%)	Manufacturer	-$280
Sodium Thiosulfate	Manufacturer	-$420
Replacement Media	Manufacturer	-$1,600
Heating of Cleaning Solution	$0.115/kWh	-$1,200
Annual Operational Savings		**$17,000**

Inland Desalination Crossover

The application of multimedia filters coupled with UF membranes extends beyond shipboard systems to inland desalination plants. *"Compared to conventional chemical and physical based water treatment, ultrafiltration membrane systems require significantly less space and often have lower labor, chemical, and waste disposal costs"*.[16] Aside from the space requirements, differences exist in the feed water sources. The proposed system is designed for variable seawater quality in littoral regions, so inland sources of brackish water will not pose a problem for the membrane. Concerns with the direct application into inland plants lie in the production of the concentrate stream from the membrane. Common disposal methods include direct surface water discharge and sewer discharge, which are viable in coastal regions but not inland due to freshwater contamination.[17] The inland plant must address this issue with the RO reject, and the HF concentrate should be treated in a similar manner. Because of disposal problems, the proposed system should operate at higher water recoveries, minimizing waste from the UF membrane. HF systems have achieved water recoveries of 90%.[16] Higher recoveries for the proposed pretreatment process can be expected because brackish water instead of turbid seawater is used for inland desalination. *"Feed water properties, product water quality requirements, site conditions and specific project economics vary and must be carefully considered before using this process"*.[16] The proposed system is an attractive alternative to current physicochemical pretreatment of RO systems where "plant space is limited" and there is *"high turbidity and variable feed water"*.[16]

Regulations

Currently, the Oceans and Coastal Protection Division of the Environmental Protection Agency (EPA) has the task of preventing marine pollution. Under the National Pollutant Discharge Elimination System, vessel discharges incidental to the normal operation of a vessel into the waters of the United States are required to submit a notice of intent if the vessel is over 300 gross tons. The Vessel General Permit (VGP) is applicable to 26 specific discharge streams, including concentrated seawater produced as a byproduct of the processes used to produce freshwater from seawater. Following the VGP, brine from the reject water *"shall not contain or come in contact with machinery or industrial equipment (other than that necessary for the production of potable water), toxic or hazardous materials, or wastes."*[18] Some states, e.g., Hawaii, have additional regulations which prohibit the formation of objectionable sludge or bottom deposits. The discharges from the proposed pretreatment design meet these regulations.

The National Defense Authorization Act of 1996 amended Section 312 of the Clean Water Act to require the EPA and the Department of Defense (DOD) to develop Uniform National Discharge Standards (UNDS) for discharges incidental to the normal operation of a vessel of the Armed Forces. Although only in the second phase of three phases, the discharges of the proposed system will eventually be subject to the mandates of the UNDS. Phase I identified RO discharge brine as having the potential to cause adverse environmental effects because significant amounts of metals are discharged at concentrations above the water quality criteria. In this process, which employs multimedia filters followed by UF membranes, the concentration of metals in the discharges from the system will not be changed because they do permeate the UF membrane. The use of the RO reject for backflushing redirects an existing stream that may contain metal concentrations exceeding water quality standards into the system, but the design does not alter this concentration. The thermal effects of discharges were determined to be negligible.

Chemical Considerations

Residual chlorine from the cleaning cycle needs to be completely eliminated before it can enter the RO membrane. Sodium hypochlorite solutions are frequently used aboard vessels to prevent biofouling, and the generated waste is continuously discharged when seawater cooling systems are in operation.[19] *"There are no Federal water quality criteria for chlorine. The most stringent state water quality criterion is 7.5 µg/L"*.[19] The 200 ppm solution is 0.2 g/L, which is an unacceptable direct discharge into the water; additionally, dilution with other system discharges does not meet the state criteria either. Abiding by this law and protecting the sea environment requires dechlorination before the cleaning solution discharges into the ocean. Neutralization with sodium thiosulfate produces sodium chloride, sodium sulfate, and water, all of which can be discharged in accordance with the strictest state regulations.

Worker Safety

The primary safety measures for the proposed system are

prevention and training. The coupled filtration devices are operated at 45 psig, so care should be taken when maintaining the system. Since the system is automated, workers need to be aware of the electrical dangers involved. The cleaning solutions may be hazardous to human health, and under OSHA standards, personnel must be trained on the hazards of each chemical. Materials Safety Data Sheets also need to be onboard and available for each of the prescribed chemicals. While cleaning the UF membrane, workers should wear appropriate Personal Protective Equipment, including chemical gloves and eye protection, all conforming to OSHA standards. In order to prevent injury to personnel and damage to equipment, the tag-out program should be implemented for all equipment, components, and systems (mandatory aboard USN ships). MIL-STD-882 provides the protocol for implementing a safety program for the life of the system if used on military vessels.

Additional Regulations

Installation and use of the proposed pretreatment design aboard sea vessels requires conforming to standards unique to shipboard operations. The system needs to be able to withstand shock loadings and vibrations and also needs to be electromagnetically compatible with surrounding equipment. For use aboard military ships, these requirements are categorized in MIL-S-901D, MIL-STD-167-1A, and MIL-STD-461. The process also needs to meet all ship noise requirements (84 dB TWA, OPNAVINST 5090) and be made from materials that will not create toxic fumes during fires in enclosed spaces (MIL-STD-2031).[1] Militarization of the pretreatment process involves removal or enclosure of all plastic parts and the removal of pipe threaded parts.1 The full-scale system is easily applicable and adaptable to such standards.

Conclusions and Recommendations

1. Multimedia filtration followed by ultrafiltration is the most viable green pretreatment method for seawater reverse osmosis. The process removes particles down to 0.1 µm to minimize the fouling potential of the RO feed stream and to prolong the life of downstream RO membranes.
2. The combination of backwashable multimedia filters with backflushable UF membranes minimizes the need for re placement elements, maintenance and operating time, and chemical additives.
3. Automated backwashing, backflushing, and cleaning protocols allow operation of the multimedia filters for several years and maintain high permeation rates through the UF membranes. The performance of both units re turns to original levels following backwashing of the multimedia filter and chemical cleaning of the UF unit.
4. The operating unit requires 250 ft3 of process space and 25 ft3 of storage space for 9 months, which is below the task specifications of 300 ft3 and 100 ft3.
5. The total capital investment for the designed process is $230,000. The annual operational savings is $17,000. The payback period is 14 years. However, as savings are highly dependent on replacement frequency of all components, ships operating in coastal waters may realize greater savings of up to $47,000 annually, reducing the payback period to 5 years.
6. It is recommended that long-term (90-day) pilot plant testing be conducted. Tests will confirm projected membrane service times and can address increasing the recovery rate in the HF units. The use of actual coastal seawater, instead of a surrogate mixture, is recommended to more closely approximate conditions encountered at sea.
7. Before constructing any inland desalination units, pilot plant testing should be conducted to fine-tune the process to the specific feed conditions in that area. Altering the backwashing and backflushing schedule for less turbid feeds can significantly increase the amount of permeate produced. Membrane recovery should also be increased to minimize discharges.

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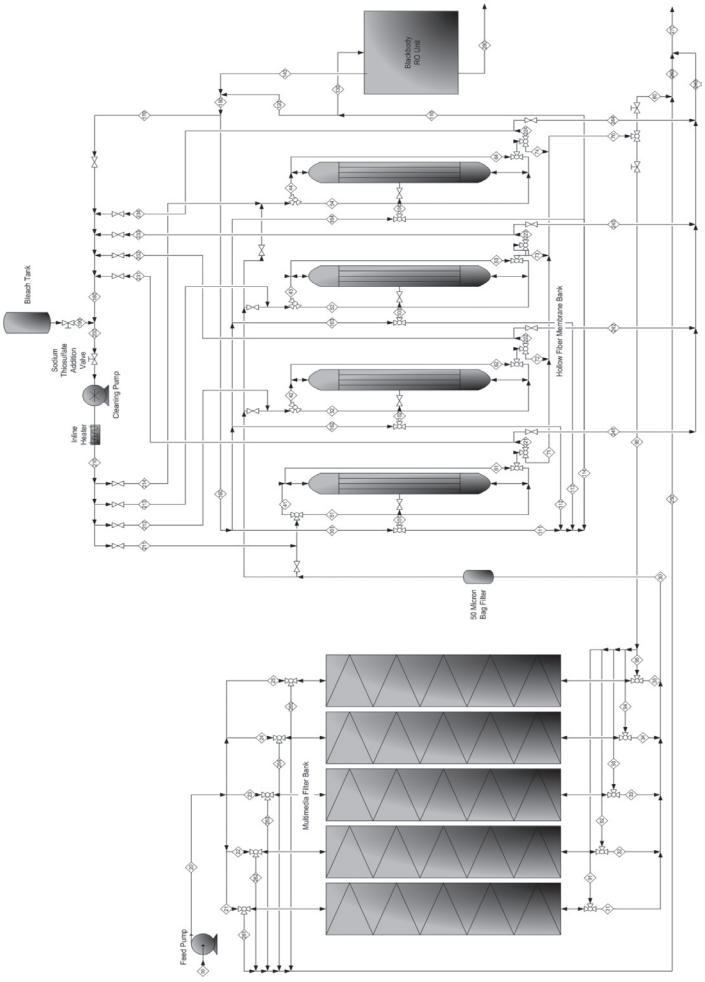
Mentor Comments: Professor Roy Penney explains the work of the team of seniors who competed successfully in a US Navy sponsored research competition. Because Inquiry typically publishes single author manuscripts, Angela Mehner was chosen to represent the group.

A team of 5 Chemical Engineering Seniors- Bartels, Mansell, McKnight, Mehner and Paul (the Seahogs)–competed in Task 4 of the 2010 WERC (http://www.werc.net) competition. The task was sponsored by the US Navy and was titled, "Green RO Pretreatment" and its objective was described on the WERC website as "Develop and demonstrate an alternative to disposable filters or an improved disposable filter design that can last at least four months filtering somewhat turbid feed water". The "disposable filters" protect shipboard potable water Reverse Osmosis Systems (RO) from foulants present in raw seawater. The Seahogs team started work on this Task January 4, 2010 and finished the competition as New Mexico State University on April 4-8, 2010. The team each received 3 credit hours for CHEG 4443, Senior Chemical Engineering Design II. The US Navy is most interested in this work because shipboard RO systems have the following problems when ships operate in coastal waters: (1) the existing prefilters must be changed frequently and (3) the existing depth filters do not have the solids removal capability to adequately protect the expensive RO modules from damage by small particulates, particularly algae. Replacing depth filters and RO modules is expensive and labor intensive. The Seahogs (working independently, except for fabrication help) developed an elegant, ingenuous solution to the problem, which totally eliminates the replacement of depth filters and protects the RO modules from particulates down to 0.05µm in size. The Seahogs design prevents any algae from reaching the RO modules. The system is totally automated and requires little operator attention, except for occasionally loading a weak bleach cleaning solution and adding sodium thiosulfate to neutralize the bleach cleaning solution. The excellent performance of the Seahogs team was rewarded by a panel of WERC judges - which included US Navy personnel - with a 1st place award for Task 4 of the 2010 WERC competition.

Appendix: Full-Scale Unit Process Flow Diagram



ADVERTISERS' ADHERENCE TO THE FTC'S GREEN GUIDES: A CONTENT ANALYSIS OF ENVIRONMENTAL MARKETING CLAIMS

By Charlotte Muse
Department of Journalism

Faculty Mentor: Ignatius Fosu
Department of Journalism

Abstract

In 1992, the Federal Trade Commission created the Guides for Use of Environmental Market Claims, with revisions made in 1996 and 1998. The Guides designate how the Commission applies Section 5 of the FTC Act, which prevents unfair or deceptive practices, to environmental claims. Based on the increased proliferation of environmental marketing claims, the FTC has decided to again revise the Guides. The purpose of this study was to examine whether the environmental claims present in print advertisements are included in the current FTC Guides and whether the qualifying language surrounding claims is acceptable, poorly explained, not explained, or meaningless. Advertisements from two time periods were selected for a comparison of types and qualification of claims. These time intervals represent a period of stringent regulation during which the Guides were revised (1996 – 1998) and a more recent period of less stringent regulation (2006 – 2008). A content analysis was conducted for full-page environmental print advertisements published during these periods in National Geographic, Audubon, Sierra, and People Weekly. Findings from this study suggest there were more environmental claims not identified within the Guides in the less stringent regulatory period (2006 – 2008). The study also suggests claims published during the more stringent period (1996 – 1998) were more likely than those in the 2006-2008 time period to contain qualifying language that, according to the Guides, was considered acceptable. The FTC was correct to begin a revision, as many claims did not appear within the current Guides. Further specification or clarification of general claims may strengthen this category. Many claims fell within the "other" category and may need to be specified more clearly in the revised Guides.

Introduction

Green marketing first gained attention in the 1970s, and the idea truly emerged during the 1980s. The introduction of green products more than doubled to 11.4% of all new business products between 1989 and 1990 and grew to 13.4% in 1991. During this same time period, green print advertisements grew by 430% (Ottman, 1993). In 1990, over nine percent of products introduced included some form of green marketing claim. Some advertisers distributed accurate information, but others exaggerated or made false environmental claims in order to appeal to environmentally concerned consumers (Welsh, 1991). A 1990 survey by J. Walter Thompson Co. found that 96% of consumers felt they needed more information to understand claims (Levin, 1990).

In response to the increase in environmental claims, individual states began to pass laws governing their use. Problems associated with the regulation of green marketing claims led to the call for "nationwide regulation of green marketing" (Welsh, 1991, p. 994). To improve enforcement, the National Association of Attorneys General requested in March 1990 that the Federal Trade Commission work with the Environmental Protection Agency and state officials to develop national guidelines for environmental marketing. In July 1991, the FTC began holding public hearings to consider guidelines for firms making environmental claims. The hearings led to the issuance of the FTC's *Guides for Use of Environmental Marketing Claims in July 1992* to "reduce consumer confusion, help establish a level playing field for competition, and reduce the legal risk for marketers" ("Facts for Business," 2009, p.1).

The FTC Act enables the Commission to bring legal action against false or misleading marketing claims (FTC, 1998). The Guides designate how the Commission applies Section 5 of the FTC Act, which prevents unfair or deceptive practices, to environmental claims (FTC, 1998). According to the FTC policy statement on deception, claims within advertisements are considered deceptive if "there is a representation, omission or practice that is likely to mislead the consumer acting reasonably in the circumstances, to the consumer's detriment" ("FTC Policy Statement on Deception," 1984, p. 1). The Guides provide general criteria on how environmental claims should be substantiated; contain information that makes it clear to consumers whether the claim applies to the product, package, or both; qualify claims to avoid consumer confusion; and provide a clear basis for comparisons.

When the Guides were issued in 1992, the FTC established a three-year review that allowed the Commission to seek public opinion to determine whether the Guides should be revised. The review focused on "the effect of the Guides on green marketing, the state of consumer knowledge and perception of environmental claims, and whether additional terms should be included in the Guides" (Starek, 1996, p.1). The Commission also measured "trends in the frequency, content, and format of green claims on supermarket product labels" (Mayer, Cude, Gray-Lee, and Scammon, 1995, p. 1) and found that the number of environmental claims had increased substantially between 1992 and 1994, which suggested the Guides had not discouraged the use of environmental claims.

On October 4, 1996, the Commission completed the first stage of review and issued the updated Guides. The changes made were minor and included the addition of the "chasing arrows" symbol to the recycled section, an example to the ozone friendly section, and

the specification that broad environmental claims, such as "environmentally preferable," should include qualifying language to limit "the superiority claim to the particular attribute or attributes for which the claim can be substantiated" (Mayer et al., 1995, p. 3).

The 1998 revision of the Guides made clear that "recyclable" claims include "the reuse, reconditioning, and remanufacturing of products or parts in another product" ("FTC Expands Definition of 'Recyclable' and 'Recycled' Claims, Agency Updating Its 'Green Guides,'" 1998, p. 1). "Recycled content" was clarified to include "only those products or packages that were reused in the form of 'raw materials' in the manufacture or assembly of a 'new' package or product" ("FTC Expands Definition of 'Recyclable' and 'Recycled' Claims, Agency Updating Its 'Green Guides,'" 1998, p. 1). Examples were added to the above categories as well as to the "compostable" category. The Guides were also clarified to show that they apply to services marketing and marketing via the Internet and email.

Since 1983, Green America's Green Business Network has expanded from 345 members to nearly 5,000, a growth rate of about 1,350% ("Environmentally Friendly Businesses on the Rise," 2009). The increase in environmental marketing claims, environmentally friendly businesses, and new technology and innovations has led to increased concern about the application of the FTC's Guides. Because of this concern, the FTC has decided to revise its Guides earlier than originally planned to guarantee that they are applicable to the current marketplace and consumer understanding of environmental claims ("Reporter Resources: The FTC's Green Guides," 2009). The Commission has held several public workshops on issues that may be included in the revised Guides. These issues include a formal review of claims regarding carbon offsets, renewable energy certificates, and green building issues (Friel, 2008; "FTC Reviews Environmental Marketing Guides, Announces Public Meetings," 2007).

Carbon offsets are financial projects or donations designed to reduce greenhouse gas emissions and offset emissions elsewhere ("FTC Reviews Environmental Marketing Guides, Announces Public Meetings," 2007). These funds are given to third-party validated offset projects, such as renewable energy in the form of wind farms or reforestation efforts. In 2007, corporations and consumers in the United States spent more than $54 million on carbon offset credits (Story, 2008). The sale of offsets in the United States is expected to continue to increase to comply with President Obama's proposed 80% reduction in global warming emissions by 2050 (Schmidt, 2009).

As carbon offsets become more prevalent in today's "greener" culture, consumers continue to gain exposure to the purchase of carbon offsets and carbon neutrality. For example, corporations such as Travelocity and Expedia give customers the opportunity to offset the carbon emissions associated with their trips (Velasquez-Manoff, 2010). Since these claims are becoming more prevalent and may have a greater effect on consumers in the future, it is necessary for the FTC to discuss carbon offset claims in the upcoming revision to the Guides.

Several studies of consumer behavior indicate that consumers are inclined to purchase products with environmental benefits (Kalafatis, Pollard, East, and Tsogas, 1999; Mainieri, Barnett, Valdero, Unipan, and Oskamp, 2001; Todd, 2004; Reiser and Simmons, 2005). According to a recent report by the National Marketing Institute, consumers with environmental concerns represent more than $230 billion in spending power (Friel, 2008). In 2007, a Cone Consumer Environmental survey found that "91% of consumers form a positive image of a company that showcases its environmental responsibility while 85% said they would switch brands or product affiliation because of a company's negative corporate responsibility practices" (Billups, 2008, p. 2).

Consumers have continued to follow the green buying trend, even during the economic recession that began in 2007. When asked how the state of the economy affected their decisions to purchase green products, 51% of consumers surveyed said their buying habits were unchanged, and 19% had increased their consumption of green products. Only 14% said they were consuming less. The survey also found that 30% of consumers could not tell whether environmental claims in advertisements were true, while 10% said they believed information contained in environmental advertisements (Jackson, 2009).

Basing their study on Ajzen's Theory of Planned Behavior, Kalafatis et al. (1999) examined consumers' intentions to buy environmentally friendly products. This theory investigates the influences that attitudes, personal and cultural determinants, and preferences have on consumers' intentions to purchase environmentally friendly products. The results, which were in agreement with Ajzen's theory, explained the purchase intention for environmentally friendly products and showed that social influences have a significant impact on belief formation (Kalafatis et al., 1999). Accurate information and qualification of claims are necessary for consumers to comprehend product features and their respective benefits to the environment.

Mainieri et al. (1997) investigated whether environmental attitudes predict actual consumer behavior. An attitude is defined as "an enduring set of beliefs about an object that predisposes people to behave in particular ways toward the object" (Mainieri et al., 1997, p. 191). The authors hypothesized that positive environmental attitudes would be reflected in people's actions, such as recycling or buying environmentally friendly products. These hypotheses were supported. Consumers' positive beliefs about the environment predicted the number of goods purchased because of the presence of environmental claims on products, the positive impact on purchase decisions of claimed environmental features, and general environmental buying behaviors. This finding lends credence to the importance of measuring consumer comprehension of environmental claims within advertisements and their qualification. The results of the study also suggest that advertisers are more likely to place advertisements in environmentally themed magazines in order to best reach their target audience of environmentally concerned consumers.

Reiser and Simmons (2005) studied ecolabels associated with environmental information related to tourism and their effects on tourists' decisions and consumption. The study was based on a previous finding that tourists had positive attitudes toward the Green Globe 21 (GG21) ecolabel in New Zealand and appeared to be highly aware of sustainability issues. Reiser and Simmons (2005)

added brochures, PowerPoint presentations, and posters to the GG21 logo of the Christchurch Visitor Information Center. They then observed and recorded the number of visitors to the Center and the number of collected brochures containing the ecolabel. Visitors also completed surveys. Consumers who expressed concerns about the environment had more positive attitudes toward the environment compared with consumers who were ambivalent. There was also evidence that, when there was little consumer knowledge of the meaning of an ecolabel, consumer interest was low.

Polonsky et al. (1998) analyzed whether environmental information on packaging was misleading. The objective of their study was to establish the accuracy of information on packaging for 20 representative brands of dishwashing liquid. The authors hypothesized that an extensive amount of environmental information would be misleading. Results suggested that 36% of the information was "acceptable," but 64% had "no explanation," was poorly explained, or was "meaningless." A majority of images, licensing agreements, and general environmental claims information were "acceptable" (Polonsky et al., 1998). Polonsky et al. concluded that the FTC's existing regulations failed to motivate firms to provide "completely accurate environmental information" (Polonsky et al., 1998, p. 290).

The study by Polonsky et al. (1998) provided a basis for the content analysis of environmental information on product packaging by defining the categories of misleading information. Content analysis studies conducted by Polonsky et al. (1998), Kangun et al. (1991), and Carlson et al. (1993) suggest the proliferation of environmental marketing claims and their tendency to be misinterpreted. These studies did not examine the frequency of the appearance of claims covered within the current FTC Guides in advertisements or the adequate qualification of these claims as specified within the FTC's Guides. Examining the types of claims included in advertisements and the extent to which these claims are qualified would give a better understanding of the current state of environmental advertisements.

Hypotheses and Research Questions

Two hypotheses were developed regarding whether or not claims are found within the current Guides and the qualifying language surrounding claims.

$H_{1:}$ There will be significantly more environmental claims (not found within the current FTC Guides) in environmental advertisements printed from 2006 to 2008 than in advertisements printed from 1996 to 1998.

H_2: Environmental claims in environmental advertisements printed from 2006 to 2008 (a period of less stringent FTC regulation) will contain more qualifying language, as specified by the current FTC Guides, than environmental claims made in environmental advertisements printed from 1996 to 1998 (a period of more stringent FTC regulation).

The first hypothesis was based on the assumption that new technology and innovations have led to the increased use of environmental claims that are not present in the FTC's guidelines. The second hypothesis was based on a study by Abernethy and Franke (1998) of the relationship between "… the amount and type of advertising information reported in prior research… [and]…the stringency of advertising regulation" (p. 240). The study found that advertisements during periods of less stringent FTC regulatory activity contained more information. Thus, strict advertising may reduce the amount of information provided to consumers, and advertisers may be more likely to qualify environmental claims during less stringent periods of FTC regulatory activity.

In addition, the current study addressed the following research questions concerning the types of environmental marketing claims and the language surrounding them:

RQ1: Which environmental claims, whether covered or not covered by the current FTC Guides, appear in advertisements?

RQ2: Which claims are more likely to be qualified in accordance with the current FTC Guides?

Methods

A content analysis was conducted for environmental advertisements published in magazines during periods of strict regulation (1996 to 1998) and more lenient regulation (2006 to 2008). Express claims asserted directly within advertisements were examined. Through a comparison of advertisements printed from 1996 to 1998 with those printed from 2006 to 2008, it was possible to identify differences between claims in advertisements printed during the two periods. In addition to representing more current advertisements, advertisements printed from 2006 to 2008 were published 10 years after the Guide's last revision. The goal was to examine the amount of qualifying environmental information suggested by the current FTC Guides. Whether the information was "acceptable," "poorly explained," "not explained," or "meaningless" was judged based on categories of misleading or deceptive environmental claims developed by Polonsky et al. (1998).

An environmental advertisement is defined as an advertisement in which an environmental claim is present. Nature and ecology magazines were chosen because they target audiences interested in environmental issues and education. Studies show that there is a link between positive beliefs about the environment and the intent to purchase environmentally friendly products (Mainieri et al., 1997). Therefore, advertisers targeting this segment of consumers are more likely to advertise in nature and ecology magazines.

After receiving training in the use of the coding instrument, which included defining each measure and how measures would be applied, two coders individually coded 3% of the total number of environmental advertisements sampled to determine intercoder reliability. These sample advertisements were taken from *Parks & Recreation* magazine. Disagreements and variations between coders were discussed and clarified. Coding was done independently after the coders reached an acceptable agreement level exceeding a Scott's pi of .70 (see Warren, Wicks, J., Wicks, R., Fosu, and Donghung, 2007). A Scott's pi of .84 was reached after the sample advertisements were coded. Other measures to achieve acceptable levels of reliability included defining "category boundaries with maximum detail" (Wimmer & Dominic, 2002, p. 166) and con-

ducting a pilot study. Only full-page environmental advertisements were analyzed in order "to enhance readability" of environmental claims (Carlson et al., 1993, p. 32).

The sample consisted of magazines with high circulations taken from the Standard Rate and Data Service (SRDS) magazine category "Nature and Ecology" (SRDS). Full-page advertisements in *National Geographic, Sierra,* and *Audubon*, which have three of the top circulations among nature and ecology magazines, were considered. The purpose and content of these magazines are to offer views on environmental lifestyles, problems, and topics.

National Geographic is published monthly and has a circulation of over 5 million (Mediamark Research & Intelligence, LLC, *National Geographic*, 2009). The average length of a magazine subscription is 12 years, and 68% of subscriptions are renewed. *National Geographic* also reaches 47.9% of opinion leaders, which is the highest percentage of this audience reached by all magazines ("*National Geographic* Media Kit," 2006).

Sierra has a total paid and verified circulation of 599,400 (Mediamark Research and Intelligence, LLC, *Sierra*, 2009). The Sierra Club, an organization established in 1892 to promote the exploration and protection of the environment, publishes the magazine. The Sierra Club is on the forefront of the environmental movement and encourages conservation and environmental awareness, which is reflected in its publication *Sierra*. Of *Sierra* readers, 39.4% also regularly read *National Geographic* ("Sierra Club," 2009).

Audubon has a total paid and verified circulation of 401,544 (Mediamark Research and Intelligence, LLC, *Audubon*, 2009). The content of the magazine is targeted toward "nature and wildlife enthusiasts, outdoor adventurers, and environmentalists" (Mediamark Research and Intelligence, LLC, *Editorial Profile*, 2009). The National Audubon Society, an organization dedicated to preserving and restoring ecosystems and natural habitats, publishes the magazine every other month (*Audubon*, 2010). Of its readers, 26% participate in environmental groups or causes, 59% are environmentally conscious, 71% are willing to pay more for a product that is environmentally safe, and 42% have "used environmentally friendly products in the last six months" ("*Audubon* Media Kit," 2009, p. 10).

Advertisements from *People Weekly*, a publication categorized as general editorial, were also examined. With a paid and verified circulation of 3,691,819, the magazine has the highest circulation among magazines within the categories "Entertainment, Lifestyle & Popular Culture" and "News Publications" ("Mediamark Research and Intelligence, LLC, *People Weekly*, 2009). Readers have a relatively high median household income of $67,178, and nearly 7 million readers have a household income of over $100,000, which suggests that they can afford environmental products that are more expensive ("Monroe Mendelsohn Affluent Survey," 2008). *People Weekly* was examined to assess whether environmental advertisements appear in a general publication and whether advertisers feature different content for a general audience versus an environmentally conscious audience. Since the magazine is published weekly instead of monthly, environmental advertisements from issues published the first week of each month were analyzed. Previous research (Stemple, 1952) supports the premise that a sample size of 12 issues of a newspaper was sufficient to represent the sample accurately.

Operational Definitions of Variables

The environmental marketing claims examined were general claims, degradable, biodegradable, recycled content, compostable, recyclable, refillable, ozone safe, ozone friendly, and carbon offset. The operational definition of an environmental marketing claim is any marketing claim that positions a product as being more beneficial or less harmful to the environment than comparable products.

As defined by the FTC's *Guides for the Use of Environmental Marketing Claims* (1998), "degradable" and "biodegradable" claims state that products will break down and return to nature. General claims, such as "eco-friendly" or "eco-safe," offer a general environmental benefit. "Compostable" claims are used for products or packages that will break down or become part of usable compost. "Recyclable" claims are associated with products that can be collected, separated or recovered, and used again or reused in the manufacturing of another product. "Recycled content" claims state that a product is made from recycled material or the percentage of recycled content in the product is given. "Refillable" claims mean that the product can be returned for refill or may be refilled by the consumer. "Ozone safe" and "ozone friendly" claims are associated with products and packaging that do not harm the atmosphere by depleting the ozone layer. "Carbon offset" claims are identified by any given definition of carbon offset, its effects, or the specific amount of emission reduced. "Renewable" claims indicate that the product or service may be returned to a like-new state and reused. "Other" claims are those that offer a specific environmental benefit not included in the previously mentioned categories.

Polonsky et al. (1998) developed categories based on how likely advertisements were to mislead consumers. These categories were labeled "acceptable" or adequately justified with information explaining the meaning of and reason for stating the claim; "poor explanation" or not justified with enough information to make a clear claim; "no explanation" or lacking information with which to evaluate the truthfulness of the claim; and "meaningless" or "too broad" (Polonsky et al., 1998, p. 285). An example of an acceptable claim would be "20 percent post consumer waste plastic is used in the packaging of this product." A claim with a poor explanation would be "The product is made from recycled plastic." This claims is poorly explained because it fails to address the percentage of the product that is made up of recycled plastic. A recycled claim with no explanation would simply state that the product is "recycled" without stating the percentage or part of the product that is recycled. Finally, an example of a meaningless claim might be the simple assertion, "Save our World" (Polonsky et al., 1998, p. 285).

For general environmental claims to be adequately qualified, "claims may convey that the product, package or service has specific and far reaching environmental benefits" (FTC, 1998, p. 5). Degradable, biodegradable, or photodegradable claims "should be qualified to the extent necessary to avoid consumer deception about: (1) the product or the package's ability to degrade in the

environment where it is customarily disposed; and (2) the rate and extent of degradation" (FTC, 1998, p. 6). Compostable claims should indicate that the package can be "safely composted in a home compost pile or device," (FTC, 1998, p. 7) or that the package is not suitable for home composting. Recyclable claims should be qualified so that consumers can determine whether the claim refers to the product or package. A recycled content claim "should be adequately qualified to avoid consumer deception about the amount, by weight, of recycled content in the finished product or package" (FTC, 1998, p. 10). An example of an acceptable recycled content claim is that "the product contains 20% recycled fiber." A refillable claim is adequately qualified if "a system is provided for: (1) the collection and return of the package for refill; or (2) the later refill of the package by consumers with product subsequently sold in another package" (FTC, 1998, p. 13). Ozone safe and ozone friendly qualifications should state that the product does not harm the ozone or contain an ozone depleting substance. Carbon offset claims are not defined within the current Guides but are being considered for the revision to the Guides because of their increased appearance in advertising claims. Carbon offset claims are considered acceptable if a definition of carbon offsets is given and the amount of reduction in emissions is specified.

Pilot Test Results

A pilot test of the coding instrument and the hypotheses was conducted using advertisements printed in Parks & Recreation. The hypotheses were retested in the actual study, and the advertisements coded in Parks & Recreation were not included in the results. In the pilot study, 20 full-page advertisements were analyzed. Five were taken from each year: 1996, 1998, 2006, and 2008. The analysis revealed that 50% of advertised products fell in the "other" product category and featured playground equipment and turf. These categories were not added to the coding instrument.

The results were inconsistent with the first hypothesis, which predicted there would be significantly more environmental claims not found within the current FTC Guides in environmental advertisements printed from 2006 to 2008 than in those printed from 1996 to 1998. All environmental claims coded in the pilot study were discussed in the current Guides. A majority of the claims were considered general.

Results were partially consistent with the second hypothesis, which predicted that environmental claims in advertisements printed from 2006 to 2008 would contain more qualifying language, as specified by the current Guides, than environmental claims in advertisements printed from 1996 to 1998. Advertisements printed from 1996 and 1998 contained more claims that had "no explanation" or were considered "meaningless" than did advertisements printed from 2006 and 2008, though advertisements from both time periods shared a similar number of claims with "acceptable" or "poor" explanations.

Following the pilot study, no additional categories were added to the coding instrument. Levels of acceptability for all environmental claims were well defined by the instrument. Additional examples of general environmental claims, featured in advertisements coded in the pilot study, were added to the instrument. A complete analysis of advertisements in National Geographic, Sierra, Audubon, and People Weekly during the specified time frames was used to determine whether the data were consistent with the hypotheses. Since the data were nominal, a Chi-squared test was used for the analysis.

Results for Main Study

The sample of magazines in the main study produced 185 environmental print advertisements during the six-year period. Because more than one environmental claim could be coded in each environmental advertisement, more claims (n = 270) than advertisements were coded. Six different categories of claims were coded in the advertisements: general claims, biodegradable, recyclable, recycled content, carbon offset, and "other."

Claims Within and Outside of the Current Guides

The first hypothesis focused on the time periods during which the advertisements were printed. During a period of less stringent regulation (2006 –2008), 44.9% of the claims coded were covered within the current Guides, while 55.1% were not. In advertisements printed during a more stringent regulatory period (1996–1998), 78.7% of claims coded were covered in the Guides, and 21.3% were not ($\chi 2 = 28.57$, $df = 1$, n = 270, $p < .001$). Advertisements containing environmental claims not currently covered within the Guides appeared more frequently during the period of less stringent regulation (2006 – 2008). The number of advertisements containing "other" and carbon offset claims, which are not covered in the Guides, increased by 33.8% from the period of more stringent regulation (1996 – 1998) to that of less stringent regulation (2006 – 2008).

Qualifying Language Surrounding Claims

The second hypothesis focused on the time period in which more qualifying information surrounded environmental claims. During the period of stringent regulation, 69.1% of claims contained qualifying language, whereas only 40.4% of the claims had qualifying language during the period of less stringent regulation. Qualifying language was coded as acceptable, poorly explained, not explained, or meaningless based on criteria found within the Guides. During the period of stringent FTC regulation (1996 – 1998), 52.1% of claims had acceptable qualifying language, 17% were poorly explained, 21.3% were not explained, and 9.6% were meaningless. During the period of less stringent regulation (2006 – 2008), 25.6% of claims had acceptable qualifying language, 14.8% were poorly explained, 42% had no explanation, and 17.6% were considered meaningless ($\chi 2 = 22.87$, $df = 3$, n = 270, $p < .001$). These results suggest that, during a period of stringent regulation, more qualifying information surrounds environmental claims. See Appendix A for a summary of the level of qualifying language surrounding all claims.

Research Questions

To answer the research questions, advertisements were analyzed for all the years combined in order to see which claims were present and their levels of qualifying language. The first research question asked which environmental claims appeared most within advertisements. Overall, 81.8% of claims were either general or "other" claims: 45.1% were general; 36.7% "other"; 8.9% re-

cyclable; 6.7% carbon offset; 1.5% recycled content; and 1.1% biodegradability. See Appendix B for a summary of the frequencies of environmental claims in the two time periods of interest, 1996-1998 and 2006-2008.

The second research question asked which claims were more likely to be qualified in accordance with the current Guides. The data show that 37.7% of general claims were acceptable, 13.1% were poorly explained, 22.1% had no explanation, and 27% were meaningless. Most "other" claims had no explanation (58.5%), 20.2% were considered acceptable, 16.1% were poorly explained, and 5% were considered meaningless. Of the biodegradable claims coded, all had no explanation. Among recyclable claims, 78.2% were considered acceptable, 13% were poorly explained, and 8.6% had no explanation. Of the recycled content claims, 25% were acceptable and 75% had no explanation. All refillable claims were acceptable. Among carbon offset claims, 44.4% were acceptable, 38.8% were poorly explained, and 11.1% were meaningless. See Appendix C for a summary of the claims that were more likely to be qualified in accordance with the current Guides across the two time periods of 1996-1998 and 2006-2008.

Discussion

As the popularity and prevalence of environmental products rise, more attention is being given to qualifying information surrounding environmental claims in print advertisements. The FTC first responded to the increase in environmental advertisements by issuing the Guides in 1992, with subsequent revisions in 1996 and 1998. In 2007, due to an increase in the green marketplace, the FTC began conducting public hearings and research with the intention of revising the Guides. The expected issuance of the revised Guides was late 2009 or early 2010, but the release date is now uncertain due to the new administration's hold on several regulations initiated by the previous administration. This study examined environmental advertising and marketers' adherence to the Guides based on the use of qualifying language. The obtained data have important implications for those concerned about which areas should be added or strengthened in the upcoming revisions as well as how marketers' adherence to the Guides has varied from a previous, more stringent period of advertising regulation to current conditions.

Previous studies concerning environmental advertising claims (Polonsky et al. 1998; Kangun et al. 1991; Carlson et al. 1993) found that claims can be misleading on a variety of levels, as determined by the information surrounding the claim. Polonsky et al. developed categories of misleading information that were used for the development of similar categories within this study. While Polonsky et al. analyzed product packaging, print advertisements were examined in the current study, where the analyses focused on the levels of misleading information surrounding claims, the variations in misleading information during periods of high or low regulatory activity, and the presence of identified claims within the current Guides.

The results of the current study show that more environmental claims not covered by the current Guides (55.1%) appeared during the period of less stringent regulation (2006 – 2008). These claims included carbon offset and "other" claims. Conversely, 21.3% of claims from the period of stringent regulation (1996 – 1998) fell into the carbon offset and "other" claims categories. The increase in claims not within the current Guides validates the FTC's assumption that an increase in green marketing necessitates the Guide's revision. Since these claims are not discussed within the Guides, advertisers have no guidance regarding the qualification of environmental claims, which increases the probability that they may not include acceptable qualifying language. Claims that fell within the "other" category included emission-reducing incentives, fuel efficiency, renewable energy, sustainability, and cleaner energy. By examining claims that are prevalent but not covered within the Guides, the FTC can target specific areas to research and to include within the upcoming revision of the Guides.

Previous studies found that increased environmental information surrounding products and positive societal influences heighten green consumerism. Qualifying language was also examined in this study. Although it was hypothesized that more information would be found in periods of less stringent regulation (2006 – 2008), 40.4% of advertisements were coded as having acceptable or poor explanations during a period of less stringent regulation versus 69% during the period of stringent regulation (1996 – 1998). Acceptable and poorly explained claims both contained some qualifying language, though the poorly explained claims lacked some of the language necessary to properly qualify them. Meaningless claims and claims that lacked explanation contained no qualifying language. This discrepancy between the hypothesis and results may be based on the fact that, in their study, Abernethy and Franke measured the amount of general information within advertisements, not the qualifying language. The failure of claims to be acceptable resulted in the advertisers' noncompliance with the Guides.

The current lack of qualifying language within advertisements, coupled with the large number of claims not currently addressed by the Guides, indicates the need for a revision of the Guides. Ultimately, all claims should have acceptable language. The increased number of acceptable claims during the period of strict regulation may have been due in part to the release of the revised Guides. The announcement of their release, as well as any publicity that may have resulted, may have prompted advertisers to conduct their business accordingly. A higher percentage of claims advertised that were covered by the Guides may have also increased the probability that these claims would be acceptably qualified according to the Guides.

Most claims in the total sample (81.8%) were classified as "general" and "other," the two most ambiguous categories. Currently, general claims are covered within the Guides. Although 37.7% of all general claims were considered acceptable, almost a fourth were considered meaningless, suggesting a need to further clarify general claims and to develop guidelines for prevalent general claims such as "environmentally friendly." Among the "other" claims, a majority (58.5%) had no explanation, an issue that must be addressed via revised Guides by including frequently occurring claims such as emission-reducing incentives, fuel efficiency, renewable energy, sustainable, and references to cleaner energy and by developing specific instructions to qualify these claims.

Future studies could apply the classification system used in this study to assess advertisers' compliance with the Guides.

Suggestions for further study include examining multiple media formats in various time periods, which may provide greater insight into emerging environmental advertising trends. Advertisements of various sizes could be examined to see whether size has an effect on the level of qualification. Future studies could also expand the genres of magazines to determine in which publications advertisers are most likely to place environmental advertisements. Although not addressed in this paper, only 10% of the total environmental advertisements coded were found in People Weekly, with the majority (56.1%) found in National Geographic. Clearly marketers are selective in making environmental claims.

Other variables, such as where a claim appears within an advertisement, could be studied in more detail to see if a correlation exists between the variable and the level of qualification. In the current study, a majority of the products advertised fell into the product categories of services (37.3%) and automobiles (24.9%), which suggests that these product categories may be areas of concern for the FTC. Future studies could also examine the relationship between consumer attitudes and the colors and images present within environmental advertisements. In the current study, the predominant color used in environmental advertisements was green (39.7%). Advertisers may wish to attract consumers with pro-environmental attitudes by using the color most often associated with the environmental movement. Additional research could target consumers' responses towards specific colors and the connections among colors, claims, and qualifying language.

The results of the current study suggest that the FTC is correct in initiating a revision of the Guides. In fact, this revision should have been started prior to 2007 because, over the past several years, advertisers have increasingly made claims that are not covered within the Guides. Major areas of concern for the FTC are claims that fall within the "other" and carbon offsets categories. Claims in these categories have become more prevalent in recent years as a result of evolving technology and increased environmentalism. Publicity and discussion of the revised Guides in 1998 may have increased the likelihood of advertisers' adherence. Consumer education regarding environmental claims may encourage consumers to monitor advertisements and seek information. Corporate education about the revised Guides would also assist companies in making environmental claims by clarifying what is meant by an acceptable claim. Though it is hard to determine whether the FTC will be able to keep up with the rapid growth in environmental claims, the revision of the Guides to meet the demands of a changing marketplace will give advertisers a valuable resource. The revision will ideally lead to acceptable qualification and greater consumer comprehension of environmental claims.

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Mentor Comments: Dr. Ignatius Fosu explains the way in which Charlotte Muse's work is particularly relevant today since the FTC is planning to examine its current guidelines for green advertising.

Charlotte Muse's work examined green advertising with emphasis on adherence to Federal Trade Commission (FTC) regulations. The last revision of FTC regulations was in 1998. Since then, there has been a major increase in green advertising. It was therefore important to examine green advertisers' compliance with FTC regulations, what claims are currently predominant in green advertising, and whether the claims are accompanied by the appropriate qualifying language. Her work involved a thorough review and synthesis of the FTC's regulatory guidelines as well as extensive literature on the issue. She also conducted a content analysis that examined advertisers' adherence to the FTC regulations. Her study identified more claims being made by advertisers that are not covered in the 1998 FTC regulations. Based on her findings, she developed a set of very important recommendations. As the FTC has proposed to revise the regulations soon, her work makes a very important contribution to this body of knowledge. It provides key findings and recommendations that help fill a gap in the literature. Charlotte worked independently under my direction. While working on this project, she demonstrated her strength as an independent thinker and researcher. Although she used my comments in making revisions, I was impressed by her unique sense of dedication and personal determination to widen the scope of this work in order to make a unique contribution to the field.

Appendix A

Level of Qualifying Language Surrounding Environmental Claims Expressed as Percentage of Total Environmental Claims in Time Period

	1996 -- 1998				2006 -- 2008			
Claim	A	PE	NE	M	A	PE	NE	M
General	39.4%	11.7%	7.4%	9.6%	5.1%	2.8%	11.3%	13.6%
Biodegradable	--	--	--	--	--	--	1.7%	--
Recyclable	3.2%	2.1%	2.1%	--	8.5%	0.6%	--	--
Recycled Content	1.1%	--	1.1%	--	--	--	1.1%	--
Refillable	1.1%	--	--	--	--	--	--	--
Carbon Offset	4.3%	--	--	--	2.3%	4.0%	0.6%	1.1%
Other Claims	3.2%	3.2%	10.6%	--	9.6%	7.3%	27.1%	2.8%
Total	52.3%	17.0%	21.2%	9.6%	25.5%	14.7%	41.8%	17.5%

Note. A =Acceptable, PE = Poorly Explained, NE = Not Explained, M = Meaningless. Cells with a value of — indicate that no advertisements fell within this category.

Appendix B

Environmental Claim Frequency Expressed as Percentage of Total Environmental Claims in Time Period

Claim	1996 -- 1998	2006 -- 2008
General	68.0%	32.9%
Biodegradable	--	1.7%
Recyclable	7.4%	9.0%
Recycled Content	2.1%	1.1%
Refillable	1.0%	--
Carbon Offset	4.2%	7.9%
Other Claims	17.0%	47.1%

Note. Cells with a value of — indicate that no advertisements fell within this category.

Appendix C

Level of Qualifying Language Surrounding Environmental Claims Expressed as Percentage of Total Number of Claims in Respective Category During the Time Period

	1996 -- 1998				2006 -- 2008			
Claim	A	PE	NE	M	A	PE	NE	M
General	57.8%	17.1%	10.9%	14.0%	15.5%	8.6%	34.4%	41.3%
Biodegradable	--	--	--	--	--	--	100.0%	--
Recyclable	42.8%	28.5%	28.5%	--	93.7%	6.3%	--	--
Recycled Content	50.0%	--	50.0%	--	--	--	100.0%	--
Refillable	100.0%	--	--	--	--	--	--	--
Carbon Offset	100.0%	--	--	--	28.5%	50.0%	7.1%	14.2%
Other Claims	18.7%	18.7%	62.5%	--	20.4%	15.6%	57.8%	6.0%

Note. A =Acceptable, PE = Poorly Explained, NE = Not Explained, M = Meaningless. Cells with a value of — indicate that no advertisements fell within this category.

PROCRASTINATION DOES PAY SOMETIMES: HOW THE DELAY IN IMPLEMENTING BASEL II REDUCED THE EFFECT OF THE SUBPRIME FINANCIAL CRISIS

By Raymond Bart Simmons
Walton College of Business

Faculty Mentor: Tim Yeager
Sam W. Walton College of Business

Abstract

Basel II, a major international regulatory capital revision, was supposed to have been implemented in the U.S. by 2004, but delays pushed it back more than five years. Basel II could have lowered minimum capital standards and made the largest banks even more vulnerable to the subprime financial crisis and economic downturn had it been adopted before its onset in 2007. Consequently, the procrastination in implementing Basel II made the banking industry more stable as it entered the financial crisis. In this study, the assets of the 11 largest bank holding companies at year-end 2006 were separated into broad asset classes with similar default characteristics as set forth under the second Basel Accord. The hypothetical capital to be held by the BHCs against their loans and leases was computed as required under Basel II and compared with the actual capital the banks held at year-end 2006. Based on these computations, it appears that Basel II would have made banks even more vulnerable to the financial crisis had it been adopted earlier. Consequently, the procrastination in implementing Basel II benefited both the banking industry and the federal government. Among the 11 bank holding companies, total capital could have decreased by more than $170 billion under Basel II compared to the actual capital being held. The change would have amounted to a 29.7% decrease in total capital and a 52.9% drop in capital held against loans and leases, both on a weighted-average basis. Without question, Basel II needs to be adjusted to be more conservative.

Overview of the Basel Accords

Capital provides a firm with a buffer to absorb losses. All other factors being equal, more capital reduces the likelihood of failure because shareholders bear the losses, and, unlike bondholders, shareholders have no legal claim to recoup their equity investment. However, equity is expensive because shareholders require relatively high rates of return given their first-loss position. Consequently, most firms would prefer to finance their operations with a mixture of debt and equity. An important strategic decision for any firm is to determine the optimal level of capital. As a firm's level of equity increases, investors are willing to purchase the firm's debt at relatively low interest rates. In unregulated markets, a firm will choose a capital level that balances the high cost of capital with the lower cost of debt issuance to achieve a low overall cost of capital. Banks, however, operate in regulated markets.

Following the wave of bank failures during the Great Depression, Congress created the Federal Deposit Insurance Corporation to insure domestic deposits. Deposit insurance provides banks with incentives to reduce capital and increase debt (including deposits) because insured depositors are willing to lend their funds to banks at risk-free rates of return regardless of the bank's level of capital. Since the market cannot effectively discipline banks' incentives to hold an appropriate amount of capital, bank regulators must step in to ensure that minimum capital levels are held. The Basel Capital Accord is a regulatory framework that establishes minimum capital holdings for banking organizations.

Basel I, drafted in 1988 and implemented in the US in 1992, was the first international accord to set uniform, international capital standards (BIS, 2003.) The innovation of Basel I was to adjust minimum capital requirements for a bank's credit risk. Over time, however, Basel I was criticized by the industry as being too insensitive to a bank's true credit risks. In the late 1990s, development of Basel II was begun to help better align bank risk and the capital held at each bank.

Although Basel II contains three methods for determining capital requirements, the United States has adopted only the most complex method, called the advanced measurement approach (AMA). Even then, only the very largest banks—perhaps the largest dozen—will implement Basel II. The other 7,000+ banks will continue to operate under Basel I. Basel II has drawn criticism from some regulators and analysts for two primary reasons. First, as Emmons, Lskavyan, and Yeager (2005) argue, the different methods of computing minimum capital requirements can result in giving Basel II banks a competitive advantage over Basel I banks. Second, Basel II may exacerbate economic business cycles because it requires relatively small amounts of capital during booms and large amounts of capital during recessions.

The competitive advantage issue between Basel I and Basel II can be shown by comparing the capital requirements for a generic $200,000 retail mortgage loan. Under Basel I, all retail mortgages are put into the 50% risk weight bracket. The current economic conditions or the creditworthiness of the borrower has no bearing on this determination of risk. The risk-weighted assets for the loan would be $100,000, derived by multiplying the risk weight by the value of the loan. Basel I specifies that banks hold a minimum of 8% of risk-weighted assets in the form of capital; therefore, the minimum required capital for the loan would be $8,000.

Basel II places emphasis on the bank's internal assessment of risk instead of assigning loans to predetermined buckets with arbitrary risk weights (BIS, 2005.) The necessary capital under Basel II requires internal estimates of the probability of default (PD), loss given default (LGD), and the correlation factor (R), which is discussed in greater detail later. As an example, let's assume that

PD, LGD, and R equal 1.17%, 20.3%, and 0.15, respectively. To determine the loan's required capital percentage, the bank would put the variables into the following formula provided by the regulators:

Capital requirement (K) = LGD × N [(1 - R) ^ -0.5 × G (PD) + (R / (1 - R))^0.5 × G (0.999)] - PD x LGD

By doing so, the bank would compute the capital requirement for the residential mortgage under Basel II to be $4,516 or 2.26% of the value of the loan.

This simple comparison of the required capital for the same loan under Basel I and Basel II illustrates the possible competitive advantage for banks operating under Basel II. If a bank can fund a loan with less equity, its overall cost of capital is lower, which potentially allows it to lend at lower interest rates and take away business from other banks. Calem and Follain (2007) performed some benchmark calculations that suggested a significant potential shift of market share and income to the largest banking institutions in the mortgage market. In addition, Berger (2006) studied the likely competitive effects of the implementation of Basel II capital requirements on U.S. banks in the market for credit to small and medium enterprises (SMEs). He found only relatively minor competitive effects on most community banks because the large Basel II adopters tend to make very different types of SME loans to different types of borrowers than community banks. However, there may be significant adverse effects on the competitive positions of large Basel I banking organizations.

A second concern with the Basel II framework is that it is procyclical, encouraging banks to hold less capital during periods of economic growth and more capital during recessionary periods. Kashyap and Stein (2004, p. 28) write that "our simulations suggest that the new Basel II capital requirements have the potential to create an amount of additional cyclicality in capital charges that is, at a minimum, economically significant, and that may be—depending on a bank's customer mix and the credit-risk models that it uses—quite large." Gordy and Howells (2006) argue that the "new capital standards will exacerbate business cycle fluctuations. In brief, the idea is that, in a downturn when a bank's capital base is likely being eroded by loan losses, its existing (non-defaulted) borrowers will be downgraded by the relevant credit-risk models, forcing the bank to hold more capital against its current loan portfolio. To the extent that it is difficult or costly for the bank to raise fresh external capital in bad times, it will be forced to cut back on its lending activity, thereby contributing to a worsening of the initial downturn.

Research Question

This paper addresses the cyclicality of Basel II by estimating the potential reduction in capital requirements for banks adopting Basel II had the new framework been adopted just before the onset of the financial crisis in 2007. The AMA approach enables banks to use internal estimates to determine minimum capital requirements, and the default probability of a loan is a key estimated input. If banks underestimate "true" default probabilities, they may end up holding less capital than necessary. For example, mortgages and mortgage-backed securities had historically low default probabilities prior to the recent financial crisis. Due to their history of low default risk and high credit ratings, it could be hypothesized that, under Basel II, most banks would have held lower capital against their mortgages and mortgage-backed securities than they held under Basel I. Consequently, during the surge of sub-prime residential lending, large quantities of these securities would not have been properly assessed for their credit risk.

Thus the research question is, would Basel II have lowered minimum capital standards and made banks even more vulnerable to the financial crisis had it been adopted before the onset of the crisis? If so, the procrastination in implementing Basel II made the banking industry more stable as it entered the financial crisis.

Research Methodology

In determining the Bank Holding Companies (BHC) to include in this sample, the 11 largest banks were selected according to total assets as of December 31, 2006, the period of time just before the onset of the crisis. Implementing the Basel II Accord requires more time and effort from the BHCs; therefore, it would have been adopted by only a select number of the largest institutions as determined by the United States regulators. The bank holding companies used in this research are shown in Table 1:

Table 1. Bank Holding Company Total Assets As of December 31, 2006 ($000s)

Bank Holding Company	Total Assets
Citigroup, Inc.	1,884,318,000
Bank of America Corporation	1,463,685,485
JPMorgan Chase & Co.	1,351,520,000
Wachovia Corporation	707,121,000
Wells Fargo & Company	481,996,000
HSBC North America Holdings, Inc.	478,025,477
Taunus Corporation	431,865,000
Barclays Group US, Inc.	261,111,792
US Bancorp	219,232,000
Countrywide Financial Corporation	199,946,230
SunTrust Banks Inc.	182,161,609

The next step was to find the account values for all of the loans and leases at each of the BHCs so that these values could be mapped into the Basel II capital formula. These loan numbers can be located in Schedule HC-C, Loans and Lease Financing Receivables in the FR Y-9C filings, which are the report forms on the consolidated financial statements to be filed by bank holding companies with total consolidated assets of $500 million or more. The Schedule HC-C shows the full breakdown of the company's loans and leases on their balance sheets. The main categories include real estate loans, loans to financial institutions, commercial and industrial loans, loans to individuals, and other loans. [1]

Next, loans and leases as reported in FR Y-9C were converted to the classification system used in the Basel II Accord. Under the Internal Ratings Based approach to Basel II, banks must allocate

[1]The schedule also allocates account balances as domestic and/or consolidated. In order to obtain the individual account balances for all real estate loans, I had to solve for foreign real estate holdings. The foreign real estate was only included in the total consolidated figure for real estate loans. Therefore, foreign real estate can only be found using the total consolidated loans secured by real estate and subtracting the sum of all loans secured by real estate in domestic offices. This process allows the total loan values to equal the BHCs' total consolidated loans and leases as reported.

their exposures into different classes of assets with different underlying risk characteristics. Unlike the classification system used for loans in the FR Y9-C reports, loans and leases made according to Basel II are categorized by five main groupings: corporate, sovereign, bank, retail, and equity. Beyond the five main classes, the corporate asset class is divided into five sub-classes, and the retail asset class is separated into three separate sub-classes. The FR Y9-C loan categories can be mapped into the following eight Basel II categories:

Retail Mortgage:
- ✓ Revolving, open-end loans secured by 1-4 family residential properties and extended under lines of credit
- ✓ Closed-end loans secured by 1-4 family residential properties

Qualified Revolving Retail Exposures:
- ✓ Credit card and other revolving credit plans

Small and Medium Enterprise Retail:
- ✓ Loans to finance agricultural production and other loans to farmers
- ✓ Lease financing receivables

Other Retail:
- ✓ Other consumer loans including single payment, installment, and all student loans

Wholesale Corporate:
- ✓ Commercial and industrial to U.S. and non-U.S. addresses (domicile)

Wholesale Bank:
- ✓ Loans to U.S. banks and other U.S. depository institutions
- ✓ Loans for purchasing and carrying securities
- ✓ Loans to foreign banks
- ✓ All other loans to financial institutions

Wholesale Sovereign:
- ✓ Loans to foreign governments and official institutions

Small and Medium Enterprise Corporate:
- ✓ Construction, land development, and other land loans
- ✓ Commercial real estate loans secured by non-farm non-residential properties, multifamily residential properties, or farmland
- ✓ Foreign real estate holdings

The next step was to determine the estimates for the three main variables in the required capital formula under Basel II: the probability of default, the loss given default, and the exposure at default. Probability of default is the chance that a given loan will enter into default before it reaches maturity expressed in the form of a percentage. Loss given default is defined as the portion of the initial loan balance that will not be recovered if the borrower defaults on the loan. To correctly calculate the probability of default for the different asset classes requires knowledge of the number of loans that went into default for the given period and prior periods compared to the total number of loans outstanding of a given type. Unfortunately, all of the financial statement data on the FRY-9C forms are account balance totals. No information is provided on individual loans.

Fortunately, the Fifth Quantitative Impact Study conducted by the Bank for International Settlements on 382 banks worldwide estimates the PD and LGD for each sample BHC (BIS, 2006.) This impact study was the last trial run of Basel II to evaluate the potential changes in the minimum required capital levels under Basel II; thus, it contains the most recent changes proposed to the accord in June of 2004 prior to its delay because of the economic crisis. The appropriate data to use were those from the weighted-average estimates of PD and LGD across all eight asset classes of the G10 Group 1 because of its relevance to the 11 banks chosen for this study. Exposure at default (EAD) was set at the total value of the loans and leases for each of the asset classes. The estimates of PD and LGD gathered from the Fifth Quantitative Impact Study were used for each of the 11 BHCs in the sample and are shown in Table 2.

Table 2. Estimates of PD and LGD for G10 Group 1 Banks from QIS5

	Retail			
	Retail Mortgage	Qualifying Revolving Exposure	Other	Small and Medium Enterprise
Loss Given Default (LGD)	20.3%	71.6%	48.0%	46.2%
Probability of Default (PD)	1.17%	2.95%	3.45%	2.99%

	Wholesale			SME Corporate
	Corporate	Bank	Sovereign	
Loss Given Default (LGD)	39.8%	40.9%	33.3%	35.0%
Probability of Default (PD)	0.99%	0.27%	0.12%	2.10%

A key determinant of the riskiness of an asset is its sensitivity to adverse economic events. The formula for calculating required minimum capital for Basel II requires a systemic correlation factor which measures the relationship between different types of loans and some unspecified adverse event. For instance, imagine that a bank has two loans outstanding with a value of $50,000 each. The first loan is to a blue-collar worker with no savings, and the second is to a local businessman with a large net worth. If the economy turns for the worse, the blue-collar worker is more likely to lose his job and be forced to default on the loan despite all attempts to pay it off. Although still affected by the economic downturn, the local business person is more likely to repay the loan.

This sensitivity to outside factors could also be based on the type of asset or other factors. While the formula for the systematic correlation factor is similar for all bank exposures, the ranges of correlations differ between retail and non-retail exposures. For corporate, bank, and sovereign exposures, the maximum and minimum correlations are set at 0.24 and 0.12, respectively. However, for retail exposures, the systematic correlation factors range from 0.03 to 0.16. For results between the maximum and the minimum, the correlation for each asset class differs because of the use of the historical average probability of default as the sole input in the formula. The higher the average probability of default, the lower its systematic correlation will be, and vice versa. For example, if a loan has an extremely high probability of default, the external factors cannot increase the chances for default much higher than they already are; therefore, the correlation factor will be lower. For retail mortgages and qualifying revolving retail exposures, the correlation factors are given as 0.15 and 0.04, respectively, without the use of a formula.

Correlation (R) for corporate, soverigh, or bank exposure =
$$0.12 \times (1 - EXP(-50 \times PD)) / (1 - EXP(-50)) + 0.24 \times [1 - (1 - EXP(-50 \times PD)) / (1 - EXP(-50))]$$

Correlation (R) for retail exposure =
$$0.03 \times (1 - EXP(-35 \times PD)) / (1 - EXP(-35)) + 0.16 \times [1 - (1 - EXP(-35 \times PD)) / (1 - EXP(-35))]$$

The final components in capital formula for non-retail exposures are the maturity adjustment and average maturity. The weighted-average maturity of all loans except the residential mortgage loans were obtained from Schedule RC-C of the Federal call reports for each of the BHCs. The problem is that call reports are done on the bank level and not by the bank holding company. Consequently, each BHC was matched with its national- and state-chartered banks. Schedule RC-C of the call report divides residential mortgages and other mortgages into the following maturity brackets: three months or less, three months to a year, one to three years, three to five years, five to fifteen years, and over fifteen years. A weighted-average formula was then created to compute the average remaining maturity of non-residential mortgages to be used in the maturity adjustment, which only applies to non-retail exposures. The formula used the median of each of the maturity brackets times the value of the loans in that bracket. The next step was to take the sum of the brackets and divide that value by the sum of all of the brackets to end up with the weighted-average maturity of all loans for that type. Under Basel II, the maturity adjustment is calculated using the following formula:

Maturity adjustment (b) = (0.11852 – 0.05478 × ln (PD)) ^2

Last, the required minimum capital ratio for each BHC was determined by using the formula and these inputs: PD, LGD, EAD, correlation factor, maturity adjustment, and average maturity. As a reminder, the maturity portion of the formula is only used for corporate, bank, and sovereign bank exposures.

Capital requirement (K) = LGD × N [(1 - R) ^ -0.5 × G (PD) + (R / (1 - R))^0.5 × G (0.999)] - PD x LGD

Capital requirement (K) = [LGD × N [(1 - R) ^-0.5 × G (PD) + (R / (1 - R))^0.5 ×
w/ maturity adjustment G (0.999)] – PD x LGD] x (1 - 1.5 x b) ^ -1 × (1 + (M - 2.5) × b)

To find the actual dollar value of required capital, the required capital percentages were simply multiplied by the EAD to calculate the actual capital required under Basel II for each loan type. To illustrate, the required capital calculated for a consumer loan is 5.5%, and the loan value is $20,000. Since EAD equals the value of the consumer loan, the required capital is $1,100 or 0.055 x $20,000. Then, the required capital was totaled for each asset class to determine the amount of capital under Basel II based on previous assumptions to be held for each bank holding company. Remember that the required capital is only the capital to be held against the loans and leases of the BHCs.

In order to find the estimated amount of total regulatory capital, the difference between the estimated capital held against loans and leases and the actual capital held had to be calculated and then subtracted from the total regulatory capital the bank holding company held as of December 31, 2006, under Basel I regulations. Even though the consolidated financial statements clearly stated the total regulatory capital held as of December 2006, the capital being held only against the loans and leases was needed. The actual risk-weighted assets held against loans and leases were multiplied by the total risk-based capital ratio. This allowed the most direct comparison between the real capital being held against loans and leases and the estimates resulting from the research. To get the actual capital held, Schedule HC-R of the FR Y9-C for the BHCs was used to find the total risk-based capital. The following demonstration shows the steps to calculate the estimated amount of total regulatory capital for Bank of America Corporation.

1. Calculate the risk-weighted assets of the loans and leases
2. Multiply the risk-weighted assets ($) by the total risk-based capital ratio:

   RWA x TRBC = Capital LnL
   560,812,349 x 11.88% = 66,624,507

3. Subtract the actual capital from the estimated capital held against loans and leases:

   Actual Capital LnL – Estimated Capital LnL = Difference Capital LnL
   $ 66,624,507 – $ 33,334,731 = $ 33,289,776

4. Subtract the difference in capital for loans and leases from the actual total capital:
   Actual Total Capital – Difference Capital LnL = Estimated Total Capital
   $ 125,225,775 – $ 33,289,776 = $ 91,935,999

In order to calculate the estimated risk-weighted assets according to the estimate of Basel II capital derived in this study, the capital was divided by the total risk-based capital ratio. First, eight percent was used as the TRBC because it is the minimum level acceptable under Basel II. Next, the risk-weighted assets were calculated based on the risk-based capital ratio unique to the bank holding companies as of December 31, 2006. For all 11 institutions, the ratios were higher than the required ratio of eight percent, resulting in an even lower figure for risk-weighted assets.

After completing the estimations of required capital and risk-weighted assets under the Basel II, the actual data from the bank holding companies for comparison were looked up. Schedule HC-R Regulatory Capital gives loan and lease value totals and allocates them to the correct risk-weight bucket. Therefore, to calculate the actual risk-weighted assets for the BHCs as of December 31, 2006, the values for each bucket were multiplied by the corresponding risk weight and added together to get the total risk weighted assets (BIS, 2005.) However, the total reported capital must also be equal to the sum of loans and leases held for sale and loans and leases, net of unearned income, as reported in Schedule HC: Consolidated Balance Sheet. Hence, the same calculation was performed for both the loans and leases, net of unearned income, and the loans and leases held for sale. The need for this calculation was particularly evident when it became apparent that some institutions had a majority of their loans and leases classified as held for sale. An important note is that, even though an institution may be attempting to sell loans, it still controls the loans. The bank holding company is still required to hold the capital against the loans just as if they planned to hold them in portfolio.

Results

Based on the results of this study, Basel II would have made banks even more vulnerable to the financial crisis had it been adopted earlier. Consequently, the procrastination in implementing Basel II benefited both the banking industry as a whole and the federal government. Among the 11 bank holding companies,

total capital could have decreased by more than $170 billion under Basel II compared to the actual capital being held. The decrease would have amounted to a 29.7% decrease in total capital and a 52.9% drop in capital held against loans and leases, both on a weighted-average basis. For example, Citigroup Inc., the largest BHC as of December 2006, held $68.1 billion in capital against its loans and leases. According to the calculations, Citigroup Inc. could have held as little as $31.3 billion in capital against its loans, a decrease of 54.1%. Overall, the 11 banks held $321.3 billion in capital against their loans and leases compared to the $151.3 billion minimum capital that was calculated under Basel II.

For total capital held, the differences between the actual and the estimates under Basel II remain the same as those from the capital held against loans and leases. This similarity is due to the fact that Basel II applies only to the calculation of required capital in a BHC's loan and lease portfolio. However, the percentage changes in total capital still illustrate the degree to which the banking industry would have suffered further during the recent economic crisis. Wells Fargo, for example, had total capital of $51.5 billion at year-end 2006. Even today, banks are still struggling with new foreclosures and high loan losses. Just imagine how much worse off Wells Fargo would be today if it had held only $30.1 billion in capital, as calculated using the Basel II formula for required capital. This picture would have been the same for virtually all banks that would have adopted Basel II prior to the economic crisis. All of these BHCs would have run out of capital much sooner than they actually did. The complete statistics for capital held against loans and leases, total capital, and risk-weighted assets for all 11 BHCs are presented in Tables 3 through 5 at the end of this paper.

Conclusions

The second Basel Accord was intended to promote a more forward-looking approach to capital supervision, one that would encourage banks to identify the risks they may face, today and in the future, and to develop or improve their ability to manage those risks. Despite this intent, Basel II definitely has major flaws. The main flaw is its reliance on historical data in determining a BHC's level of credit risk. The present study shows without question that Basel II needs to be adjusted to be more conservative. Although there is nothing inherently wrong in financial institutions' wanting to hold a minimum amount of capital and not one cent more than needed, it does leave the banking industry more vulnerable in times of economic downturn, as the past several years have shown. Fortunately, now that history has clearly demonstrated that there is more risk than previously thought, the implementation of Basel II is somewhat self-correcting. The key internal estimates made by each BHC will be altered to be more conservative, thus hopefully providing a safer financial position for the banking industry in the years to come. Nevertheless, a portion of the change should come from changes to the Basel Accord and its formulas. Indeed, regulators are currently preparing what some are calling "Basel III" to be released by year-end 2010. (BIS, 2009.)

Table 3. Capital Held Against Loans & Leases ($000s)

	Actual Capital	*Hypothetical Basel II Capital*	*Percent Change*
Bank of America Corporation	*66,624,507*	*33,334,731*	*-49.97%*
Barclays Group US, Inc.	*1,730,225*	*730,694*	*-57.77%*
Citigroup, Inc.	*68,060,733*	*31,248,100*	*-54.09%*
Countrywide Financial Corporation	*8,177,335*	*2,828,537*	*-65.41%*
HSBC North America Holdings, Inc.	*27,355,553*	*10,847,357*	*-60.35%*
JPMorgan Chase & Co.	*49,903,491*	*20,318,755*	*-59.28%*
SunTrust Banks, Inc.	*12,125,812*	*6,964,409*	*-42.57%*
Taunus Corporation	*-1,287,955*	*1,450,179*	*-212.60%*
US Bancorp	*16,538,133*	*7,636,451*	*-53.83%*
Wachovia Corporation	*34,867,305*	*20,072,791*	*-42.43%*
Wells Fargo & Company	*37,184,413*	*15,845,438*	*-57.39%*
Total	*321,279,550*	*151,277,443*	
Equally weighted percent change in capital			*-68.70%*
Weighted average percent change in capital			*-52.91%*

Table 4. Total Capital ($000s)

	Actual Capital	Hypothetical Basel II Capital	Percent Change
Bank of America Corporation	125,225,775	91,935,999	-26.58%
Barclays Group US, Inc.	3,491,551	2,492,021	-28.63%
Citigroup Inc.	123,260,000	86,447,367	-29.87%
Countrywide Financial Corporation	17,031,228	11,682,430	-31.41%
HSBC North America Holdings, Inc.	38,338,644	21,830,448	-43.06%
JPMorgan Chase & Co.	115,265,000	85,680,264	-25.67%
SunTrust Banks, Inc.	18,024,866	12,863,463	-28.63%
Taunus Corporation	-3,776,000	-1,037,865	-72.51%
US Bancorp	24,495,000	15,593,318	-36.34%
Wachovia Corporation	60,194,000	45,399,487	-24.58%
Wells Fargo & Company	51,427,000	30,088,025	-41.49%
Total	572,977,064	402,974,957	
Equally weighted percent change in capital			-35.34%
Weighted average percent change in capital			-29.67%

Table 5. Risk-Weighted Assets of Loans and Leases ($000s)

	Actual Risk-Weighted Assets	Hypothetical Basel II Risk-Weighted Assets	Hypothetical Risk-Weighted Assets @ 8% RBC
Bank of America Corporation	560,812,349	280,595,381	416,684,141
Barclays Group US, Inc.	15,097,947	6,376,043	9,133,681
Citigroup, Inc.	584,212,300	268,224,032	390,601,247
Countrywide Financial Corporation	63,885,430	22,097,947	35,356,716
HSBC North America Holdings, Inc.	245,561,518	97,373,047	135,591,968
JPMorgan Chase & Co.	405,060,800	164,924,958	253,984,435
SunTrust Banks, Inc.	109,143,221	62,685,948	87,055,111
Taunus Corporation	33,280,500	-37,472,332	18,127,241
US Bancorp	131,463,700	60,703,110	95,455,640
Wachovia Corporation	307,743,200	177,164,972	250,909,892
Wells Fargo & Company	297,475,300	126,763,501	198,067,970
Total	2,753,736,265	1,229,436,608	1,890,968,043
Weighted average percent change in RWA		-55.35%	-31.33%

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Mentor comments: Dr. Tim Yeager has nothing but praise for Bart Simmons' independence and planning in executing this important piece of research.

In October 2008, the largest U.S. banks such as Citigroup and Bank of America were on the brink of failure threatening to pull the economy into a full-blown depression. Just a few years before, regulators were so impressed with the health and stability of the banking system that they began a process called Basel II to reduce the amount of capital banks were required to hold to protect against failure. The implementation process dragged on for several years so that, even now in 2010, Basel II has never been put into effect. Had Basel II been in place on the eve of the financial crisis, how much less capital might banks have held, and consequently, how much worse might the crisis have been? Bart Simmons was an undergraduate Finance and Accounting major in my advanced banking course when we discussed Basel II. He immediately identified this as a research topic that was difficult and complicated enough to interest him, and he approached me about doing his thesis on this important topic. I don't know of any other research by students or professors alike that explores this issue. Like most students, Bart set aggressive deadlines for working on his project. Unlike most students, he met or exceeded those deadlines. Bart worked independently on his research, including making his way through complex statistical formulas. With little guidance from me, he constructed and completed his empirical tests. When it came time for writing up the results, Bart put together a draft of which many of my PhD students would be proud. I worked with him to polish up the rough edges, but he had clearly articulated his research question and methodology, and described the results. Bart found that procrastination does indeed pay sometimes because delays in implementing Basel II allowed the banking system to have more capital than it would have had otherwise. Bart also knows that procrastination does not pay when it comes to conducting thorough and high-quality research. He proved that as well with his timely and diligent efforts on this important topic.

FACTORS INFLUENCING BREASTFEEDING IN A HOSPITAL SETTING

Mary Smith
Department of Nursing

Faculty Mentor: Kathleen Barta
Eleanor Mann School of Nursing

Abstract

Breastfeeding is promoted across the globe as the optimum method of infant feeding (World Health Organization,WHO, 2003). Though there is a plethora of published benefits of breastfeeding for baby and mother, breastfeeding rates are below the national goal of 75% for Healthy People 2010 during early postpartum and considerably lower at six months and at one year (Li et al., 2005; HHS, 2000). Arkansas is significantly below the national average and goals, with only 60% of mothers ever breastfeeding versus 74% nationally (Centers for Disease Control and Prevention, CDC, 2008). To meet these goals nationally and on a state level, it is important to examine the factors associated with a mother's choice of breastfeeding. Part I of this study examined the relationship between breastfeeding at discharge and the mother's initial feeding preference, method of delivery, time of birth, birth-to-breast time, and any formula supplementation. It also identified which factor had the strongest relationship with rates of breastfeeding upon hospital departure. Part II of this study examined hospital nurses' attitudes, knowledge, and confidence about breastfeeding instruction as related to their self-reported assistance with and promotion of breastfeeding in the past year. Results: Exclusive breastfeeding at discharge was related to type and time of delivery, birth–to-breast time, and use of formula supplementation. Knowledge and attitude scores did not yield significant correlations with the assistance and promotion of breastfeeding, though a weak positive correlation was noted between confidence in breastfeeding promotion and the nurses' assistance and promotion of breastfeeding.

Introduction

Breastfeeding is promoted across the globe as the optimum method of infant feeding (WHO, 2003). Though there is a plethora of published benefits of breastfeeding for baby and mother, breastfeeding rates are below the national goal of 75% for *Healthy People 2010* during early postpartum and considerably lower at six months and at one year (Li et al., 2005; HHS, 2000). Arkansas is significantly below the national average and goals, with only 60% of mothers ever breastfeeding, versus the national average of 74%, and only 22.5% of Arkansas mothers exclusively breastfeeding three months after the infant's birth (CDC, 2008). Arkansas hospitals and birth centers scored only 53 out of 100 (below the national 66) for facility supportive breastfeeding practices (DiGirolamo et al., 2008). With the *Healthy People 2010* initiative, the United States Department of Health and Human Services hopes to see the national breastfeeding goals met by 2010 (Li et al., 2005; HHS, 2000). Some of the lower percentages in breastfeeding rates are caused by lower numbers of low-income and minority mothers choosing not to breastfeed (Li et al., 2005; HHS, 2000; Wolf, 2003). Other factors within the hospital setting could potentially be the cause of the gap in rates.

Though the practice of breastfeeding is dateless, its benefits have just been verified and highlighted in the past century. Throughout the twentieth century, however, breastfeeding declined as births moved out of homes and into hospitals and more physicians encouraged newly designed formulas that were thought to have more nutrients for the baby (Gibson, 2005; Wolf, 2003). In the latter twentieth century, emerging research supported the benefits of breastfeeding. This research and the resurgence of physician encouragement began to counteract declining breastfeeding rates postpartum, raising them from 24% in 1971 to just over 70% in (Gibson, 2005; Wolf, 2003).

Infant Benefits

Current research demonstrates that breastfeeding can dramatically decrease infant mortality rates (American Academy of Pediatrics, 2005; Barrett, 2004). Breastfeeding is also known to decrease gastrointestinal problems, including diarrhea, often linked to formula consumption (AAP, 2005; Gibson, 2005). Breastfeeding reduces the rate of infections in newborns and children, specifically ear, respiratory, and urinary tract infections (AAP, 2005; Barrett, 2004; Galson, 2008; Greer et al., 2008). It can also reduce atopic diseases such as asthma, eczema, allergic rhinitis, and food allergies (AAP, 2005; Greer et al., 2008). Breastfeeding is associated with dramatic decreases in pediatric obesity (AAP, 2005; Armstrong et al., 2002; Grummer-Strawn et al., 2004) and with reduced risk for the development of type 1 diabetes mellitus (AAP, 2005; Sadauskait -Kuehne et al., 2004). Breastfed infants also show an increase in neurological development and have a decreased risk of Sudden Infant Death Syndrome (SIDS) (AAP, 2005; Barrett, 2004). Acting as a natural analgesic, breastfeeding can assist in comfort measures for infants during painful medical procedures (AAP, 2005; Gray et al., 2002).

Maternal Benefits

Not only does breastfeeding have an overwhelming benefit for the baby, but mothers reap benefits as well. The skin-to-skin contact associated with breastfeeding develops and enhances a maternal-child bond (AAP, 2005; Britton et al., 2006; Dabrowski, 2007). Furthermore, breastfeeding mothers are less likely to suffer from postpartum depression (Akman et al., 2008). Additionally, breastfeeding increases the rate of return of the mother's body to a pre-pregnancy state (AAP, 2005; Dewey et al., 1993; HHS, 2000). Breastfeeding mothers also show a significant decrease in the risk for breast and ovarian cancers (AAP, 2005; Chilvers, 1993; Galson, 2008; Gwinn, 1990; HHS, 2000). Further, a decrease in the risk of developing osteoporosis and hip fractures after menopause has also been linked to mothers who breastfeed (AAP, 2005; Cumming et al., 1993; Fox et al., 1993; HHS, 2000). Surprisingly, breastfeeding benefits women in the workplace by decreasing time off for sick children and lowering costs of health care to the employer (Cohen et al., 1995; Galson, 2008). The mother and the family greatly benefit from the decreased or eliminated cost of formula and a decrease

in health care costs in the child's future (AAP, 2005; Ball, 1999).

Factors Influencing Breastfeeding Rates

Infants benefit from breastfeeding long term. The AAP recommends exclusive breastfeeding for six months and support for breastfeeding through the first year and beyond as desired (AAP, 2005). However, a number of factors influence a mother's decision to continue breastfeeding over time. Attitudes and social support of the mother affect exclusive breastfeeding at 6 months (Bai et al., 2010). Mode of delivery could affect exclusive breastfeeding; research suggests that mothers need even greater support in breastfeeding following a caesarean birth (Baxter, 2006). Time of birth could also affect in-hospital breastfeeding as formula supplementation is most likely to occur between 7 PM and 9AM (Gagnon et al., 2005). The World Health Organization (1998) reported that getting an infant to the breast within 30 minutes of a normal vaginal delivery correlated with exclusive breastfeeding at 2-3 months of age. A study of Japanese women showed a strong correlation between exclusive breastfeeding at four months and a maximum birth-to-breast time of 120 minutes (Nakao et al., 2008). Formula supplementation in the hospital has been shown to decrease the length of breastfeeding (Sheehan, 2006; Tender et al. 2009). A lower rate of exclusive breastfeeding during the hospitalized postpartum period could relate to the substandard rate of long-term breastfeeding (Tender et al., 2009).

Mothers learn about breastfeeding techniques and its benefits in a variety of ways. Women associate with friends or family members who have breastfed infants in the past and can view the practice positively or negatively depending on the observed experience of others (Williams et al., 1999). Prenatal and parenting classes may also include breastfeeding education. A great deal of education on breastfeeding occurs in the hospital setting and is conducted by the nursing staff. In one study, 37% of mothers said in-hospital support was the most influential factor in choosing breastfeeding (Williams et al., 1999). Pender's health promotion model also identifies interpersonal influences, including health providers, as a stimulus producing a health promoting behavior (Pender et al., 2002). Breastfeeding is classified as a health promoting behavior because of its positive impact on the health of mother and baby (Schlickau et al., 2005). Nurses' attitudes towards breastfeeding, their knowledge base, and their affirmative reinforcement significantly influence the success of breastfeeding for mothers (Ellis et al., 1983; Williams et al., 1999). Unfortunately, the endorsement of formula use by hospital staff has had a stronger impact than hospital staff support and promotion of breastfeeding (Williams et al., 1999). Further, mothers who choose to use formula attribute their choice to in-hospital staff more so than do mothers who choose to breastfeed (Williams et al., 1999).

Aims of the Study

Part I of this study examined the relationships between rate of exclusive breastfeeding at discharge and the following variables: initial mother preference, method of delivery, time of birth, birth-to-breast time, and any formula supplementation. The goal was to determine which in-hospital factor, if any, had the strongest correlation with exclusive breastfeeding rates at discharge. Part II of this study examined the relationship between assistance with and promotion of breastfeeding by the nurses in the hospital setting and the variables of years in practice, level of education, personal experience, attitudes, knowledge levels, and confidence levels.

Part I

Method

Design. A retrospective chart review was conducted to gather specific data for statistical analysis. Each chart was assigned a random case number and did not contain the name of the patient or the medical record number. Variables of interest were initial mother feeding preference, method of delivery, time of birth, birth-to-breast time, any formula supplementation, and preferential feeding choice at discharge. The following variable definitions were used. *Birth-to-breast time* is the amount of time between the documented time of birth and the documented initial breastfeeding of the baby calculated in minutes. *Supplementation* is the use of infant formula exclusively or in combination with breast milk to feed the infant, measured by the act of supplementation and the number of times formula was fed to the newborn at any point during the hospital stay. *Rates at discharge* are the number of mothers who are exclusively breastfeeding at the time they are released from the hospital with their infant, measured by exclusive breastfeeding charted during the last 12 hours of their hospital admission and as indicated on the discharge summary. *Breastfeeding with supplementation* is the use of breastfeeding and formula within the last 12 hours of hospital admission.

Sample. The charts sampled in this study were those of mothers delivering term infants in an urban health care facility in Northwest Arkansas. Term infants are those who are born after 37 weeks gestation or who are not admitted to the NICU or termed 'preemie'. Birth methods included caesarean section and vaginal births. Mothers of babies admitted to the neonatal intensive care unit and mothers with illnesses or contraindications to breastfeeding were excluded from this study. Ten percent of female patient charts falling within the aforementioned criteria from January 2008-June 2008 were viewed and analyzed. The sample size was 152.

Data and Analysis. Descriptive statistics were calculated for all variables. The format for creating each variable is provided in Table 1.

Table 1. Elements for Chart Review

Breastfeeding at discharge	Breastfeeding preference upon admission	Method of Delivery	Time of Birth	Birth-to-breast time	Formula Supplementation
☐ Yes	☐ Prefer breastfeeding ☐ Prefer formula feeding ☐ No preference	☐ Caesarean Section ☐ Vaginal delivery	Note delivery time	Calculate minutes from time of birth to time of first breastfeeding	☐ No ☐ Yes ☐ If yes, how many times?
☐ No	☐ Prefer breastfeeding ☐ Prefer formula feeding ☐ No preference	☐ Caesarean Section ☐ Vaginal delivery	Note delivery time	Calculate minutes from time of birth to time of first breastfeeding or note if never breastfed	☐ No ☐ Yes ☐ If yes, how many times?
Frequency and percentages calculated	Frequency and percentages calculated	Frequency and percentages calculated	Mean and standard deviation calculated for both groups	Mean and standard deviation calculated for both groups	Frequency and percentages calculated. Means and standard deviations for the number of supplementations also calculated

Results

In the 152 charts reviewed, 101 mothers indicated exclusive breastfeeding as their initial preference for feeding method on the delivery report. Twenty-three mothers preferred bottle feeding, and 38 mothers preferred combined breastfeeding and bottle use as the source of nutrition for their infant. Only 55% of those with an

exclusive breastfeeding preference were exclusively breastfeeding at discharge. Ninety-five percent of those desiring bottle feedings initially were discharged bottle feeding. Eighty-nine percent of those who preferred breast and bottle feedings initially were discharged from the hospital using breast and bottle feedings. Of the 66% mothers who initially preferred breastfeeding alone, 33% left the hospital breastfeeding with supplementation. See Figure 1.

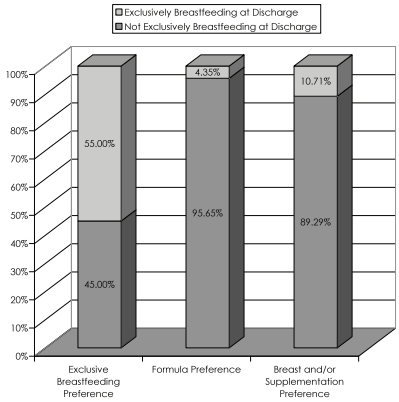

Figure 1. Exclusive breastfeeding at discharge based on mother's initial preference

Seventy-six babies were delivered by caesarean section, and 76 babies were delivered vaginally. There were no significant differences in initial feeding preference based on type of delivery. However the method of delivery influenced the rate of exclusive breastfeeding at discharge. Forty-one mothers (53.95%) with vaginal deliveries left the hospital exclusively breastfeeding, while only 17 mothers (22.37%) with caesarean deliveries left the hospital exclusively breastfeeding. See Figure 2.

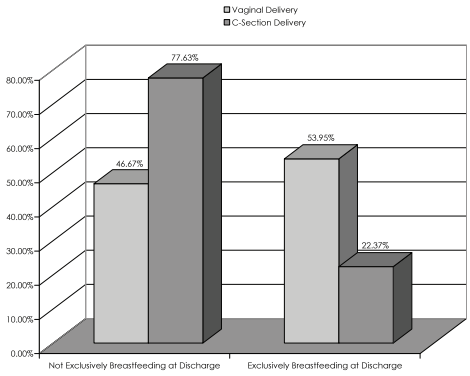

Figure 2. Exclusive breastfeeding at discharge based on method of delivery

One hundred seventeen births were reported during the day shift, and 34 births occurred during the night shift. Forty-three percent of births during the day shift were discharged exclusively breastfeeding, while only 24% of births occurring during the night shift left the hospital exclusively breastfeeding.

The average birth-to-breast time was 345 minutes, with a median of 203 minutes. Less than 25% had a birth-to-breast time of under one hour. Less than 8% of infants who were breastfeed had a birth-to-breast time that met the national standard of 30 minutes. Birth-to-breast times were significantly shorter for women who exclusively breastfed at discharge and those who were not exclusively breastfeeding at discharge (t=-6.18916, df= 69, p<.0001). Prolonged birth-to-breast times resulted in a decreased likelihood of exclusive breastfeeding at discharge. See Figure 3. The method of delivery correlated with the birth-to-breast time. The average birth-to-breast time after a vaginal birth was 4 hours and 11 minutes,while that after a caesarean section was 7 hours and 29 minutes.

Figure 3. Exclusive breastfeeding at discharge based on birth-to-breast times

Out of the 39% of the mothers who left the hospital exclusively breastfeeding, 17% received formula supplementation in the hospital. Only 10% of infants who received formula supplementation left the hospital exclusively breastfeeding. Formula supplementation was given to 67% of those in the study, although only 34% initially preferred the use of a bottle or breastfeeding with supplementation. Formula supplementation showed the greatest correlation with the rates of exclusive breastfeeding at discharge (Kendall's T = -0.7192, p<.0001).

Part II

Method

Design. Part II of this study involved the distribution and review of survey data. The survey was originally developed by Freed et al. in 1996 to examine the methods and outcomes of breastfeeding instruction for nursing students. In 2000, Register et al. revised the survey to examine the breastfeeding knowledge and attitudes of office nurses. The survey for this study was then revised for hospital nurse respondents. The revised survey contained 16 multi-part questions, with 37 data points collected. Questions were multiple choice or used a 5-point Likert-type scale with 1 being the most negative response (not confident, strongly disagree, or very negative) and 5 the most positive (very confident, strongly agree, or very positive). The survey was distributed to each nurse attending a monthly staff meeting with instructions to return the survey (if willing to complete) to the associate director's office. The survey instrument did not request the name of the respondent. Data collected from the survey included level of education; number of years in practice; breastfeeding education received; breastfeeding practices and management in the hospital to assist, teach and refer; personal experience; attitudes towards breastfeeding and the nurse's role in assistance; confidence levels in assisting with and teaching about breastfeeding; knowledge of breastfeeding; and nurse assistance and promotion of breastfeeding.

Sample. Subjects were Registered Nurses working in the labor and delivery, nursery, and post-partum areas in an urban health care facility in Northwest Arkansas. A convenience sample was used.

Analysis. Attitude, knowledge, and confidence questions using the 5-point Likert-type scale yielded a subscale score for each topic. Descriptive statistics were calculated for the subscales and variables. The relationships between the frequency of nurse assistance and promotion of breastfeeding in the past year and the following variables were examined: years in practice, level of education, personal experience, attitudes, knowledge, and confidence levels of the nurse.

Results

Twenty-five out of 27 distributed surveys were filled out and anonymously submitted (a 93% response rate). The average length of practice was 10.2 years, with a median practice time of 4 years. Years in practice was not significantly related to the assistance and promotion of breastfeeding. The sample consisted of 4 diploma registered nurses, 8 associate degree registered nurses, and 13 baccalaureate degree registered nurses, with no participants having a master's degree. Eighty-eight percent reported that some of their breastfeeding education was received on the job, and all subjects reported that some breastfeeding education had been received. Only 16% received breastfeeding education through continuing education, the lowest reported source of education for the nurses. The relationship between level of nursing education and nurse assistance and the promotion of breastfeeding was not significant.

Sixteen nurses (64%) reported having breastfed their own infants. The average length of personal breastfeeding reported was 12.6 months +/- 16.8, with a median of 9 months. The majority of those with personal breastfeeding experience reported it as a positive to very positive experience, with a mean of 4.5 out of 5. Correlation analysis of the relationship between personal experience and nurse assistance and the promotion of breastfeeding did not yield a statistically significant relationship. Attitude scores were evaluated based on the nurses' perceptions of their role in breastfeeding and the importance of exclusive breastfeeding. The maximum attitude score possible was 30 based on a 5-point Likert scale. The mean attitude level of the nurses was 21, with a median of 21. Nurses strongly to somewhat disagreed that it was their role to follow up with breastfeeding mothers, with a mean score of 2.44 out of 5 on the Likert scale. Nurses were indifferent to the statement that exclusive breastfeeding is the most beneficial form of nutrition for the infant in the first four months of life, with a mean score of 3.68. Nurses also strongly to somewhat disagreed that supplementation was a cause of breastfeeding failure, with the mean answer being 2.56. See Figure 4.

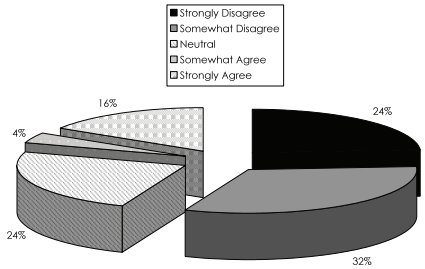

Figure 4. Self-reported opinions of 25 RNs citing formula supplementation in the first two weeks of life as a cause for breastfeeding failure

Knowledge scores were based on levels of agreement with true statements regarding breastfeeding, including health benefits to the infant and proper discharge instructions for the breastfeeding mother. The maximum knowledge score was 28; the mean in this study was 22.8 +/- 3.0, with a median of 22.5. The majority of the sample agreed that breastfed infants benefit from fewer ear infections and cases of gastroenteritis, increased immune function, and adequate weight gain without formula supplementation. Nurses provided correct discharge instructions that babies should return to birth weight in two weeks and that breasts will feel fuller prior to feeding. Neither the attitude nor the knowledge scores were significantly correlated with nursing assistance and promotion of breastfeeding.

Confidence scores were based on self-reported abilities to assist with breastfeeding and help the mother with common breastfeeding concerns. The maximum confidence score was 51. The mean confidence reported in this study was 37, with a median of 39. Nurses were most confident in their ability to work with breastfeeding mothers concerning jaundice, with a mean score of 4.04 out of 5. Nurses reported being the least confident in assisting a mother with latch difficulties and educating a mother on her medication use while breastfeeding, with a mean of 3.32 out of 5 for both questions. The confidence of the nurse had a weak positive correlation ($r = 0.28$, $p = 0.17$) with the assistance and promotion of breastfeeding, but it was not statistically significant.

Nurses cited their own efforts to assist or to refer to a lactation consultant as the most common actions taken when a patient required breastfeeding assistance. Sixty-eight percent of the sample reported observing a patient breastfeeding over 50 times in the past year. Assistance and promotion scores were based on the self-reported frequency in the past year of counseling on feeding choices, teaching of breastfeeding techniques, providing breast pump instruction, counseling a mother with lactation problems, and encouraging breastfeeding over formula use. The maximum score was 15, with this sample averaging a score of 10 and a median score at 11. The majority of the sample (54%) reported providing breast pump instruction only 1 to 10 times throughout the past year, while the majority had counseled moms on feeding choices and taught breastfeeding techniques over 50 times in the past year. See Figure 5.

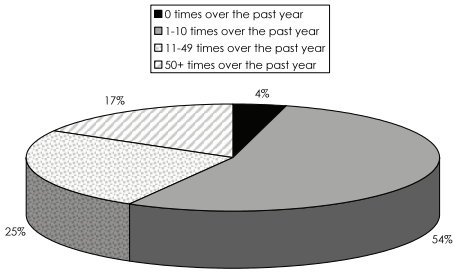

Figure 5. Self-reported frequency of breast pump instruction over the past year

Thirty-six percent had encouraged breastfeeding over the use of formula 50+ times in the past year. No factor was significantly correlated with nurse assistance and promotion of breastfeeding. See Figure 6.

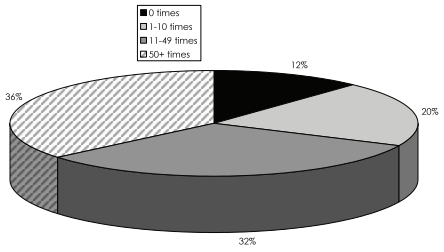

Figure 6. Self-reported frequency of encouraging breastfeeding over formula use over the past year

Discussion

Part I of this study used a chart review to examine factors influencing exclusive breastfeeding on discharge. Several factors were identified as related to exclusive breastfeeding. Caesarean delivery, births on night shift, longer birth-to-breast times, and formula

supplementation resulted in decreased rates of exclusive breastfeeding at discharge. Mother's initial preference was not significantly related to breastfeeding at the time of discharge. The majority of mothers with initial preferences for only bottle feedings or a breast/bottle combination were discharged using their preferred practice. Only 10% of those preferring both and 4% of those preferring formula were discharged exclusively breastfeeding. However, 45% of those who preferred exclusive breastfeeding were not discharged doing so.

With the *Healthy People 2010* goal of 75% breastfeeding in the postpartum period, mothers were closer to reaching the goal at hospital admission, with 66% of mothers wanting to exclusively breastfeed, than at discharge, when only 39% of the sampled population was exclusively breastfeeding. The decrease in the mothers exclusively breastfeeding at discharge is presumed to be related to factors in the hospital setting, not to prenatal care or parenting classes. One such factor might be nursing encouragement. In Part II of this study, only 36% of the nurses encouraged breastfeeding over formula more than 50 times in the past year, which is minimally once a week. Though the majority strongly agreed that breastfeeding support was an important use of their time, nurses responded neutrally to the importance of exclusive breastfeeding for the nutrition of the infant, despite its label as the optimal feeding choice for infants (WHO, 2003). The low percentage of breastfeeding promotion and an apparently apathetic attitude towards the importance of breastfeeding could explain some of the large differences in exclusive breastfeeding at discharge for those mothers who initially preferred exclusive breastfeeding versus those that accepted supplementation.

Though the initial preferences did not significantly vary between mothers having vaginal or caesarean deliveries, exclusive breastfeeding at discharge decreased with a caesarean delivery. The care a mother receives after a c-section can influence feeding outcomes (McFadden et al., 2009). Exclusive breastfeeding rates also dropped for births on the night shift. Birth-to-breast time was also an average of 3 hours and 18 minutes longer after caesarean deliveries. This is consistent with studies indicating that caesarean birth is a barrier to the early initiation of breastfeeding (Rowe-Murray et al., 2003). Research suggests that the birth-to-breast time should be thirty minutes after a normal vaginal delivery for successful breastfeeding in the future (WHO, 1998). Neither delivery method in this study yielded an acceptable birth-to-breast time. Both delivery types, time of shift during birth, and birth-to-breast time significantly influenced exclusive breastfeeding at discharge.

Finally, formula supplementation significantly decreased exclusive breastfeeding at discharge. The majority of surveyed nurses did not agree that supplementation caused breastfeeding failure, though research suggests formula supplementation in the hospital impedes long-term breastfeeding success (Tender et al., 2009; Glagnon, 2005). The lowest rate of exclusive breastfeeding at discharge was for infants who had received formula supplementation.

The nurses in Part II of the study had positive scores for attitudes, knowledge, confidence, and assistance/promotion of breastfeeding; however, they scored lowest in attitudes for all categories, which is an important finding since nurse attitudes significantly influence breastfeeding success (Ellis et al., 1983; Williams et al., 1999). Knowledge and attitude scores did not yield significant correlations with the assistance and promotion of breastfeeding. A weak positive correlation was noted between confidence in breastfeeding promotion and the nurses' assistance and promotion of breastfeeding, though it was not statistically significant. Overall, only two-thirds of the nurses assisted and promoted breastfeeding on a near weekly basis. The survey revealed that most nurses do not regularly provide instruction on breast pumps, counsel a mom with lactation problems, or encourage breastfeeding over formula. The majority do not believe it is their role to follow up or that supplementation causes breastfeeding failure.

The results of Part I are generalizable to the target population at this particular hospital. Generalizability could be increased with random samplings from other area hospitals to explain a target population of the region. The results of Part II are likely not generalizable to the target population outside of the surveyed group due to the small sample size and method of convenience sampling versus random sampling.

Nursing Implications

The results of the study have implications for nursing education and practice in order to improve breastfeeding in hospital settings to ensure that infants are receiving the best nutrition. Nurses reported low frequencies of breast pump instructions and a lack of confidence in educating mothers about medication compatibility and breastfeeding. Because pumping breast milk enables nursing mothers to return to work while still providing breast milk to the infant, nurses should educate themselves on the availability and types of breast pumps available to buy, rent, or use on their unit. Encouraging a new mother to use a breast pump in the hospital setting if she must return to work could improve her success in breastfeeding the infant long term. By gaining confidence in educating mothers about the use of medication while breastfeeding, nurses may increase how often they assist with and promote breastfeeding. LactMed is a resource that nurses can utilize to look up drugs and their compatibility with breastfeeding (US NLM, 2009).

Nurses should also gain awareness about the new *Healthy People 2020* goals for breastfeeding. By increasing the awareness of factors that can decrease breastfeeding success, such as caesarean deliveries, births on the night shift, delayed birth-to-breast times, and formula supplementation, nurses can prepare themselves to implement more interventions to assist and promote breastfeeding when these factors are present. Because in-hospital staff members influence the nutrition decisions parents make for their infants, nurses play a direct role in increasing breastfeeding rates. In addition to meeting WHO standards for breastfeeding, nurses should be aware of evidence-based practices concerning breastfeeding to provide optimal patient care. Research demonstrates that formula supplementation in the hospital can lead to long-term breastfeeding failure; therefore, measures should be taken to ensure that nutrition is properly maintained and that the mother is educated and assisted with breastfeeding, particularly if these are her wishes (Tender et al., 2009).

In the present study, the majority of mothers with initial preferences for formula feeding or breast and supplementation left the hospital practicing their initial preference, but nearly half of mothers initially preferring exclusive breastfeeding left the hospital doing otherwise. These data suggest that the hospital staff may not have been cognizant of the mother's wishes or were not

determined to fulfill her preferences during her hospital stay. The American Nurses Association Code of Ethics (2005) states that the "nurse's primary commitment is to the patient." Measures should be taken to advocate for the health of the mother and the infant and fulfill the feeding preferences of mothers.. To improve the health of patients in the maternal-newborn setting and reach future *Healthy People 2020* goals, implementing practices and attitudes that promote exclusive breastfeeding is essential.

Limitations

Limitations to Part I of the study include variations in charting methods used by nurses to document a mother's initial preference and feeding times. Exclusive breastfeeding at discharge was based on the electronic documentation of feeding methods during the final 12 hours of the hospital stay. Inaccuracies could occur if not all of the feedings were documented in that time period.

Limitations to Part II of the study include the small size of the survey sample. Scores on the survey were self-reported and may not reflect the actual practices of the nurses. The shift of the nurse could have been reported and could have potentially yielded a relationship with assistance and promotion of breastfeeding.

Future Research

Subsequent studies could explore more fully the relationship between time of birth and breastfeeding at discharge. A larger study of nurses' assistance and promotion of breastfeeding may yield statistically significant relations with attitude, knowledge, and confidence in hospital nurses. A qualitative study of the nurses' reflections on practice may help uncover additional factors that influence breastfeeding rates.

Acknowledgement

Permission to use and modify the tool was obtained from Nancy Register, RN-CS, MSN, FNP; Dietra Lowdermilk, PhD, RNC, FAAN; and Gary L. Freed, MD, MPH.

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Mentor Comments: Faculty mentor Kathleen Barta describes the persistence of Mary Smith as she pursued her research goal, helping one area facility along the way.

Mary approached me during her junior year with an ambitious idea for her honor's project very well conceptualized. She clearly identified the relevant variables from previously published work in the area of infant nutrition. Mary took my suggestions for locating a tool to measure her variables of interest. She received an Arkansas Student Undergraduate Research Fellowship (SURF) grant in the fall of 2008 to address her first aim of understanding factors affecting breastfeeding through a retrospective chart review. Negotiating resistance in the initial clinical setting where conducting research is not yet common practice was an important learning experience. She eventually switched sites and found staff willing to assist with her study. She conducted all of the chart reviews. Her eagerness to more fully understand factors affecting breastfeeding from the point of view of the nursing staff led her to successfully submit for an Honor's College grant to address her second research aim through a survey of nurses in maternal-child practice. Mary arranged permission to use a previously published survey instrument (Register, Lowdermilk, Hammond, & Tully, 2000). She worked with the hospital's clinical director to distribute the survey to staff nurses. The U.S. Department of Health and Human Services' Healthy People 2020 initiative has goals to "increase quality and years of healthy life and eliminate health disparities." The specific breastfeeding objective is to increase the proportion of mothers who breastfeed their babies. The value of Mary's study was to uncover in a particular setting some of the factors that influence current rates. She shared the results of her research with staff in the setting in an effort to remove barriers to breastfeeding and increase rates of breastfeeding of the women served by the setting. The clinical director wrote to say that Mary "presented her research…[and] did a wonderful job. We now have lots of valuable information that will help us improve our nursing practices related to breastfeeding. This was a great experience." Mary also presented her research April 12, 2010 in a poster presentation at the 19th Annual Nursing Excellence in Leadership and Evidence-Based Practice conference sponsored by the Pi Theta Chapter of Sigma Theta Tau International and the Eleanor Mann School of Nursing. During her thesis defense Mary identified several directions to extend her research in the area of breastfeeding that she could pursue during future graduate work in nursing. Mary completed her honors work while also excelling in the demanding upper division clinical coursework in nursing. She is positioned to be a future leader in nursing practice and research.

RESEARCH NOTE: AUTOMATED PATH FINDING SERVICE FOR SECOND LIFE

By Daniel Starling
Department of Computer Science and Computer Engineering

Faculty Mentor: Craig Thompson
Department of Computer Science and Computer Engineering

Second Life (a product from Linden Labs) is a 3D virtual world platform where one can create custom objects (houses, cars, pets, etc.) and embed logic in them through scripts, giving rise to a rich, interactive world made of user content. Human participants in the world are represented by "avatars" which can wander about freely in "regions" (also known as "islands") that subdivide the world into pieces that are hosted on servers on the Second Life (SL) grid (server farm located at Linden Labs). While humans have the necessary cognitive facilities to navigate this 3D environment, scripted objects do not. In particular, there are no facilities for path finding (e.g., moving from A to B via a set of waypoints that avoid obstacles). Were this feature to exist, it would become easier to implement realistic simulations and avatar-bots (avatars operated by programs instead of humans) inside of SL. As it is, every application needing this functionality implements a special case, primitive navigation for agents that move from place to place with very limited knowledge of their surroundings. This is due in part to resource concerns (e.g., CPU, memory overhead) on SL's servers.

Problem

Part of current research at the University of Arkansas concerns modeling healthcare logistics and medical workflows (e.g., medical procedures) within SL. This work falls under an umbrella project called "Everything is Alive" (EiA) [1]. In EiA, we suppose that pervasive computing exists and that objects are uniquely identifiable. Consequently, we always know where objects are located. The simulations that we carry out in SL often require moving an object (a wheelchair, a box of stents, etc.) using an agent (an avatar-bot) from location A to B. Typical static obstacles include hospital walls and medical equipment. Since SL lacks the ability to determine waypoints that avoid these obstacles (much less provide a reasonably short path), we needed to implement our own mechanism.

Path Finding Service

The solution we pursued is called the "path finding web service" (see [2] for more details). Agents in SL can contact this web service to navigate SL by providing their current location and where they want to go – the web service will return an appropriate list of waypoints that the agent can follow to avoid solid obstacles. Calculating waypoints from a 3D geometry model is a computationally intensive task, which is one reason why it is difficult to implement directly on SL's servers, which are already bustling with thousands of scripted objects. By offloading the task to our own server, we can partially avoid quota restrictions found in SL's Linden Scripting Language.

The Path Finding Algorithm

We use a path finding algorithm known as A*, which incrementally approaches an optimal solution through the use of a "cost" and "heuristic" function as it evaluates path choices. As A* searches through potential paths, it will evaluate a cost function that expresses distance traveled so far and then evaluates a heuristic function that approximates how close we are to the goal (in our case, it is approximated as a direct line between the current location and the destination). We originally used Djikstra's algorithm, which happens to be a special case of A* where there is no heuristic function (that is, the heuristic function would always evaluate to zero). This proved to be costly since the heuristic function is vital in guiding the search and avoiding the need to traverse the entire search space to find a solution – the heuristic function allows A* to "home in" on a solution.

Our algorithm based on A* works as follows:

1. Take a vertical slice of the world, allowing a reduction of 3D to 2D space. This yields rectangles derived from 3D bounding boxes of objects. See Figure 1.

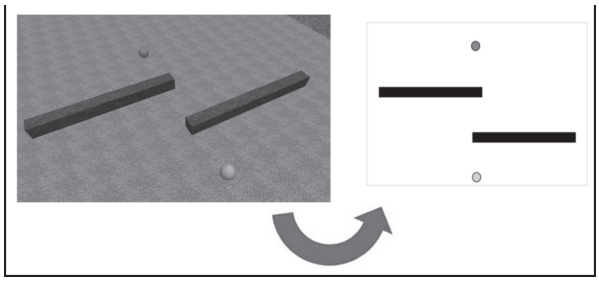

Figure 1. First step of the path finding algorithm: collapsing 3D to 2D space.

2. Expand rectangle sizes by some factor, which generally increases the amount of rectangle overlap. This avoids the problem of adjacent objects (e.g., walls) that have gaps between them (sometimes nearly imperceptible) that the algorithm would normally plot a path through, even though the object or avatar-bot that we are attempting to move through the area could not fit there. Additionally, this performs a similar duty in assuring that the entity we move through the world does not clip too close to corners or attempt to walk inside of a wall as it walks alongside it. See Figure 2.

3. Convert the rectangles into a graph, which is a data structure consisting of vertices (points) and connections between them (edges). This graph consists of the start and end points and every

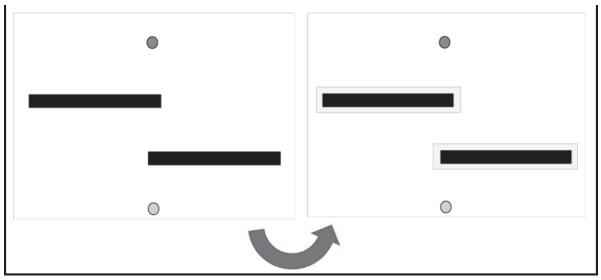

Figure 2. Second step of the path finding algorithm: rectangle size expansion.

vertex of each rectangle. Connectivity of vertices (the introduction of edges) is determined by line-of-sight reachability from one vertex to another. This is a quadratic time algorithm and becomes increasingly CPU-intensive as the number of vertices increases, sometimes rivaling A* in running time. An adjacency matrix, (a data structure that demonstrates efficient memory use for graphs with a large number of edges) stores the graph. See Figure 3.

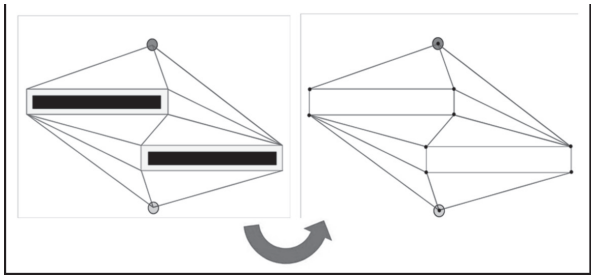

Figure 3. Third step of the path finding algorithm: conversion of rectangles and start/end points to a graph

4. Run the A* algorithm on our graph, which we have just framed as a classic single-pair shortest path problem. See Figure 4.

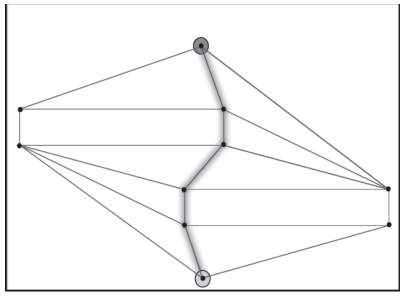

Figure 4. Fourth, final step of the path finding algorithm: apply A* algorithm to derive shortest path.

Use of the Service

The EiA project experiences considerable student churn. Undergraduate students may only be around for one or two semesters but contribute as much to the overall project as graduate students. The initial path finding web service was not very accessible to these students since it was not well-documented, relied on hard-coded parameters, and could not be updated readily as changes to layout in SL place were made (e.g., a new wall was introduced). In essence, it was not easy for new students to quickly pick up and start using the pathfinding web service in projects. Through revisions, we were able to address these issues so that a student who had just learned about Second Life (and its scripting language) could use the web service to compute paths in their own projects.

A tool was designed for student use (pictured on the left in Figure 5) that visually relates the effects of the parameters that they pass to the web server (for example, the rectangle expansion factor used in the overall algorithm). Students can also plot paths to review them for correctness and can also clear out areas of the island from the model. Re-scanning the island (done when changes take place) is just a matter of moving a special "scanner" object into position and activating it, after which it will contact the web service to report 3D bounding boxes in the world.

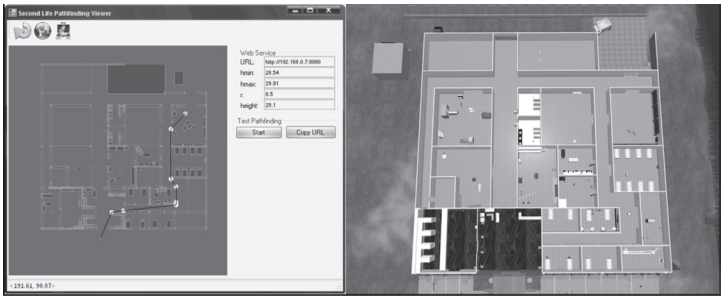

Figure 5. A visual tool for inspecting the bounding boxes with which our web service is generating a path (left) and the corresponding SL hospital on the University of Arkansas island (right).

Our final step was to release this path finding service as a package that users can set up on their own servers and use.

Discussion of Limitations

While generally useful, our design is not without shortcomings. First, to calculate a path in SL, we must be fully aware of the geometry surrounding that navigation. SL places tight restrictions on geometry export – getting a model of an entire SL island out of the SL servers and into an external format is non-trivial. We settled on a less-than-precise method that employs SL's scripted "scanner" functionality to accumulate "bounding boxes" for each object found in the world. These bounding boxes roughly describe the space that the object takes up, although it can be wildly inaccurate in some instances (e.g., L-shaped objects that appear as giant box-like solids when their bounds are inspected). The process we developed requires some "manual effort" – our scripted "scanner" object has to periodically move throughout our region of the world to read in this data and report it back to the server. This process is time consuming due to SL scripting restrictions given limits, for example, on how fast a scanner object can move and query for world geometry. Our chosen approach can be unwieldy at times; objects moved by students or changes in building architecture often require that we be able to re-scan regions. Other issues such as inconsistencies in SL's sensor implementation make scanning in geometry all the more difficult.

The second shortcoming is not so much an issue with SL but rather an area for future work. As mentioned, path finding is a resource-intensive process. To simplify the problem and generate paths in a reasonably short period of time, we do not search for paths in the entire 3D world (or region) but rather collapse a vertical slice of it on the Z-axis into a 2D "overhead view" where we can apply the custom search algorithm to derive the shortest path (see Figure 5). Since our simulations are carried out on leveled-out hospital floors, this works sufficiently well, but our solution is not scalable to more complex geographies that involve vertical movement (e.g., paths that traverse stairs or windows). A better

algorithm would implement A* in full 3D geometry with accommodation for picking paths that that are traversable by entities of varying size and limitation (e.g. gravity-bound objects).

Right now, all path computation takes place outside of SL. It is reasonable to assume that implementing path finding directly on Linden's servers is not currently feasible. Even if they were to create native, efficient functions for script-writers to use, the underlying algorithms would necessitate restrictive quotas that would likely render them less useful for the situations described in this paper.

Future Work

To make our functionality more available, we are considering the addition of the path finding service to OpenSimulator, an open-source alternative to Second Life. Hopefully, as Second Life evolves, it will offer features found in the AI component of current-generation 3D game engines, such as path finding. With such features, we would come a step closer to creating the realistic environment that Second Life's name suggests.

Acknowledgement

The author is indebted to undergraduate Nicholas Farrer, who developed the first generation path planner on which the current work is based.

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Mentor Comments: Craig Thompson's students' work with Second Life and the Everything is Alive project appear in three locations in this journal, first in Eguchi's award-winning paper, next in Kumar's manuscript, and finally in this Research Note by Starling. Each article demonstrates the diversity of research possibilities with the EiA project.

For the past three years, my research has involved how to use 3D virtual worlds like Second Life to explore what the real world will be like when every physical object is a network object, with its own identity, behaviors, and the ability to communicate with humans and other objects. In the Fall 2009, I taught Artificial Intelligence. Daniel was one of my star students. In a previous semester, one of my students Nick Farrer, since graduated, had developed a virtual world robot assembly language that included software for finding paths from a start location to and end location in the virtual world. The system used a graph of way points and an efficient path finding algorithm for searching for a route. This allowed a robot to be tasked to go from A to B in a single command. Daniel took Nick's extensive code base, understood it (never easy), and then extracted the path finding code, and repackaging it as a separate modular service that can be used for many purposes. The ability to modularly build virtual worlds up from a set of modular services is a hot topic in the virtual world architecture community at present. Daniel went a step further – he also observed that our maps of waypoints become out of date fairly quickly. So he developed a closely related service that scans an area of a virtual world for obstacles that can include walls but also furnishings or doors. We now run this second service periodically to maintain our waypoint graph in a current state. Daniel wrote a paper based on his work "Automated Path Planning for Second Life" for the X10 Workshop on Extensible Virtual Worlds (http://vw.ddns.uark.edu/X10, March 29-30, 2010). Having graduated in May 2010, Daniel went to work for a startup software company to gain real world experience but he is interested in eventually returning to academics for a Masters or Ph.D.

RESEARCH NOTE: EXPLORATION OF FACTORS THAT IMPEDE DOOR-TO-BALLOON TIMES

By Erin Troby

Eleanor Mann School of Nursing

Faculty Mentor: Ellen Odell

Eleanor Mann School of Nursing

Abstract

When experiencing an acute myocardial infarction (AMI), more commonly known as a heart attack, patients need rapid treatment in order to open up and reestablish blood flow within the coronary artery. By far, the most common way to do this is an invasive procedure that allows a physician to inflate a tiny balloon into the plaque-filled area of the artery. The American College of Cardiology (ACC) and the American Heart Association (AHA) have established a 90-minute goal for this procedure, which means that, from the time a patient enters the door of the emergency department (ED), the medical team has 90 minutes to assess, diagnose, prepare, and treat the patient with the balloon inflation procedure. The purpose of this study was to determine whether the 90-minute benchmark goal was being met in patients presenting to the emergency room with an AMI in an urban acute care hospital in Northwest Arkansas. If the time was not met, factors that influenced the delay were explored. A retrospective chart review was conducted on patients (N =70) admitted to the ED with an AMI and subsequently taken to the cardiac catheterization lab for balloon inflation between March 1, 2008 and March 31, 2009. Only 70% of the hospital's patients met the benchmark goal. Specific time intervals were studied to determine where delays were occurring, and demographic factors were examined to explore differences between groups meeting and not meeting the benchmark. Recommendations for additional research and changes in hospital procedures were made.

Introduction

Thirteen million Americans suffer from coronary artery disease, and 19% of the United States workforce is permanently disabled by the disease (Lamia, 2007). Approximately 865,000 people experience an ST-elevation myocardial infarction (STEMI) each year caused by a completely blocked artery (AHA, 2008; Lamia, 2007; Larson et al., 2007). This is a heart attack that is diagnosed by an area of elevation of more than 1 mm in the ST segment in two or more leads on the rhythm strip of an electrocardiograph (ECG). The most effective treatment for this type of myocardial infarction (MI) is a percutaneous coronary intervention (PCI) using a balloon to open the narrowed blood vessel and/or insertion of a metal device, called a stent, to keep the artery open (AHA, 2006; Pinto et al., 2006).

To improve mortality and morbidity, the American College of Cardiology (ACC) and the American Heart Association (AHA) have set a goal to reduce door-to-balloon (DTB) times from 120 minutes to 90 minutes or less (Lamia, 2007; McNamara et al., 2006; Pinto et al., 2006; Ting et al., 2008). The decrease in this time interval preserves the heart muscle, reduces the infarct size, saves lives, and lowers the number of people disabled by heart disease (Lamia, 2007; Ting et al., 2008). For every 30-minute increase in time, there is a 10% increase in the risk of in-hospital death (Pinto et al., 2006). Thus, the 90-minute door-to-balloon (DTB) time is now the gold standard of care for health care facilities. Additionally, failure to reach the 90-minute DTB time goal in 88% of patients may affect an individual hospital's accreditation and Medicare reimbursement (Lamia, 2007). When the 90-minute DTB goal has been achieved, hospitals have experienced a decrease in hospital stay by two days and hospital costs by $10,000 per admission (AHA, 2008). Nationally, between 33 to 40% of patients actually receive treatment within 90 minutes (AHA, 2008; Bradley et al., 2006; Rosamond, Flegal, & Friday, 2007).

Several events must occur in order to have a patient admitted through the emergency department to the cardiac catheterization laboratory in an expedient manner. Many hospitals have developed protocols to help guide this process and to reduce times and delays after identifying factors that impeded the ability to reach the 90-minute benchmark. These include (a) having a set protocol for chest pain patients, (b) having the ECG done within 10 minutes of arrival, (c) having the emergency physician initiate the order to move the patient to the cardiac catheterization laboratory, (d) having a single-call activation paging system, (e) having a cardiologist on site 24 hours a day, (f) setting a 20-minute time limit for cardiac catheterization laboratory staff to arrive, and (e) reviewing times and delays monthly with all staff involved in the appropriate departments (Bradley et al., 2008; Cadet, 2008; Lamia, 2007; Ting et al., 2008). Some hospitals are working to have emergency medical teams transmit the ECG to the hospital while still at the scene or en route, allowing activation of cardiac catheterization laboratory personnel before the patient arrives in the emergency department (Bradley et al., 2008; Lamia, 2007; Ting et al., 2008; UAMS, 2006). Another strategy is to have a cardiac/AMI box or cart put together with all the supplies, medications, and protocols that are needed to save time and expedite the procedures (Lamia, 2007; Bradley et al., 2006, 2008). Additional research is needed to identify opportunities for continued improvement (AHA, 2008; Bradley et al., 2006; Rosamond et al., 2007).

One urban hospital in Northwest Arkansas has already implemented several of these standards and benchmark interventions. The current study was conducted at this hospital. The purposes of this study were (1) to determine if care of patients diagnosed with an ST-segment elevation myocardial infarction met the national standard of receiving cardiac catheterization with balloon inflation within 90 minutes of arrival in the emergency department; and (2) to explore factors that impede reaching that goal. Specific research questions were the following:

Research Question #1: What proportion of patients admitted to the

emergency department with an ST elevation receive balloon inflation in the cardiac catheterization laboratory within 90 minutes?

Research Question #2: What factors differentiate the patient group meeting benchmark standards from the group not meeting standards?

Research Question #3: If there are delays in meeting the 90-minute benchmark, where do they occur?

Methodology

Study Hospital and Protocol

The study was performed at an urban acute care hospital in Northwest Arkansas. The hospital is licensed for 235 total beds, with 40 emergency department beds. The facility services approximately 50,000 patients annually and is rated as a level III trauma facility. The protocol used in this hospital is comparable to the national standards and recommendations for patients meeting the ST-segment myocardial infarction criteria. Upon admission to the emergency department, a STAT (immediate) 12-lead ECG along with a portable chest x-ray is to be completed in less than 10 minutes of arrival. When an ST-segment elevation is noted on the ECG, the cardiologist and cardiac catheterization laboratory team are notified through a paging system, and other simultaneous interventions are initiated. The following medications are administered: Aspirin, Plavix, Nitroglycerin, Metoprolol, Ondansetron, and Heparin. Additionally, blood is drawn for a complete blood count (CBC), electrolyte panel, brain natriuretic peptide (BNP), magnesium, troponin, protime (PT), partial thromboplastin time (PTT), and an international normalized ratio (INR). Nurses apply oxygen to the patient, initiate two intravenous lines, prepare the groin for the procedure by shaving the area, and ensure that operative consent forms are signed.

Sample

A probabilistic sample of certainty was used for this study. The records of all patients meeting criteria (presenting with chest pain and being transported directly from the ED to the CCL) from March 1, 2008 through March 31, 2009 were included in the study (N = 70). Patients excluded from the study were those that went to the CCL but were taken to the cardiovascular operating room in lieu of receiving balloon angioplasty due to the severity of their blockages. Another case was also eliminated because the subject experienced an ST-elevation myocardial infarction (STEMI) hours after admission to the emergency department with no complaints of chest pain or other traditional signs and symptoms upon initial presentation.

Design

The study used a retrospective chart review and a secondary data source. The secondary data source, accessed by the ED's Clinical Nurse Specialist, was the list of patients meeting the sample criteria as described above. After initial descriptive statistics were collected on the entire sample, the data were broken into two groups according to whether or not subjects met the 90-minute benchmark, and further statistical analyses were conducted to determine factors that differentiated the two groups and time segments that were significantly delayed in the group not meeting the benchmark (when compared to the benchmark group). The study protocol was approved by the Institutional Review Boards (IRB) of the University of Arkansas and the study hospital. Patient confidentiality was maintained at all times.

Variables and Analysis

The dependent variable used to classify patient groups was either "yes" (met the 90-minute goal) or "no" (did not meet the 90-minute goal). The time variables included the following intervals: (a) the patient's arrival to the emergency department to the performance time of the ECG, (b) the ECG time to when the cardiologist was paged, (c) the total time the patient spent in the ED, (d) the time the patient arrived in the CCL to the case start time, (e) the case start time to the actual balloon inflation, and (f) the total door-to-balloon time. Additional variables were gender, age, number of days spent in hospital (known as length of stay or LOS), and disposition after discharge (home, deceased, transferred to another facility, or left against medical advice). Finally, common risk factors and comorbidities associated with coronary artery disease, as identified by the AHA, were evaluated and identified for each patient. These included previous coronary artery disease, hypertension, tobacco use, dyslipidemia, family history, stroke, peripheral vascular disease, diabetes mellitus, cancer, arrhythmias, obesity, stress/anxiety/depression, presence of a coagulopathy, and renal failure.

Gender, age, length of hospital stay, number of co-morbidities, and disposition were compared between the two groups to determine whether any of these factors contributed to meeting or not meeting the goal. Differences between the two groups were then analyzed for each of the five time intervals using analysis of variance (ANOVA). The significance level for all analyses was established as $p < 0.05$.

Results

The sample of 70 patients treated with either a balloon angioplasty or a stent after an acute myocardial infarction was 67% male and 33% female. There was a wide range of ages, from 37 to 89 years; six subjects were between the ages of 18 and 39 years, 47 were between 40 and 64 years, and the remaining 17 were 65 years and older. Length of hospital stay (LOS) ranged from one to 14 days, with a mean of 3.34 days. Number of comorbidities ranged from zero to five, with a mean of 3.32.

Seventy percent (N = 49) of the patients met the benchmark 90-minute standard; the remaining 30% (N = 21) exceeded the 90-minute time frame. Distributions of gender and age clusters within each group are shown in Table 1, along with means, standard deviations, and ranges for LOS and comorbidities.

Table 1. Factors contributing to group differences.

Factor	Met Goal (N = 49)	Did not meet goal (N = 21)	Group differences
Gender (N, %)			X^2=1.36, df=1, p=.244
Male	35 (71%)	12 (57%)	
Female	14 (29%)	9 (43%)	
Age (mean, SD)	57.4 (11.8)	56.1 (11.6)	t=.401, df=68, p=.689
Age Range (N, %)			X^2=.036, df=2, p=.982
18-39	4 (8%)	2 (9%)	
40-64	33 (67%)	14 (67%)	
65+	12 (25%)	5 (24%)	
Comorbid/risk factors (mean)	2.2	2.4	t=-.538, df=68, p=.592
LOS (mean)	3.55	2.8	t=1.240, df=68, p=.219

T-tests for independent samples were used to determine whether or not the two groups differed in age, length of stay, and comorbidities. There were no significant differences between the two groups. Chi square analyses were used to determine whether the

distribution of the two groups differed with respect to age group and gender. Again, there were no significant differences in group composition. Disposition of subjects upon discharge was not compared between groups since only four patients were not discharged to the home (two within each group). Statistical outcomes are summarized in Table 2.

The five segmented time intervals were compared using one-way ANOVA. For the group not meeting the 90-minute benchmark, all time intervals were significantly longer than those for the benchmark group (see Table 2). The average time for balloon inflation for patients reaching the goal was 68.2 (SD = 16.6) minutes, with a range of 32 to 90 minutes. On average, therefore, this group fell comfortably within the benchmark timeframe. In contrast, for patients not meeting the benchmark, the average time was more than one hour longer, 151.8 (SD = 58.8) minutes, and ranged from 91 to 279 minutes.

Table 2. Analysis of variance comparisons of time intervals from door to balloon for patients meeting benchmark and those not meeting benchmark.

Time Interval	Met Benchmark		Did Not Meet Benchmark		F	
	Mean	SD	Mean	SD	(df)	p value
Door to ECG time	3.5	5.0	11.6	21.6	6.22 (1, 68)	.015
ECG to Doctor Paged	15.3	13.1	52.7	44.3	29.48 (1, 68)	.000
Total ED Time (goal < 45)	40.1	14.7	109.1	57.3	62.48 (1, 68)	.000
To CCL to Case Start	52.4	16.3	122.9	57.5	62.59 (1, 67)	.000
Case Start to Balloon Inflation	15.8	8.7	28.5	14.2	20.70 (1, 67)	.000
Total Door-to-Balloon Time	68.2	16.6	151.8	58.8	84.79 (1, 68)	.000

Discussion

This study was designed to determine whether door-to-balloon times met national standards in an urban hospital in Northwest Arkansas and, if they did not, to identify areas needing improvement in order to improve patient outcomes. While the mean times from door-to-balloon for the benchmark group were well within the 90-minute target, the group failing to meet benchmark standards was significantly slower in every time interval in the process. Thus, improvement in treatment time is needed for all time intervals studied in order to attain compliance with the standard and achieve accreditation.

The study facility had 70% of their patients meeting the benchmark--better than the national average of 57% (Rathore, Curtis, Chen, Wang, Nallamothu, Epstein, & Krumholz, 2009). However, it is important to recall that the standard for accreditation is 88% of patients presenting with AMI meeting the 90-minute benchmark (Lamia, 2007). Explanations for the low national average include the disproportionately large number of patients presenting to hospitals that are not equipped with a CCL and thus are unable to perform PCI, which requires the patient to be transferred to another facility. However, this is not the case in the study hospital. Improvement in reaching the standard is still needed.

The fact that demographic variables did not distinguish the two groups in this study was somewhat surprising. For example, it would be expected that patients who are sicker (more comorbid diseases) would have a poorer outcome. It is also logical to believe that those patients with significant risk or history of cardiovascular disease would have more complications and an increased LOS and mortality rate. This was not found to be true. Another surprising finding was the factor of age. The elderly population in general does not present with the typical signs and symptoms of chest pain, making it easier to "miss" the diagnosis. Signs and symptoms can be masked by other processes of normal aging or a dulled pain sensation. Despite these facts, age was not a significant factor in determining whether a patient was able to achieve the 90-minute benchmark. With respect to gender, there were again no significant differences between the groups. Although not part of the primary analysis in this study, it was noted that females took longer to arrive in to the cardiac catheterization laboratory (CCL), but once there, they were treated with the balloon inflation more quickly than men were. This finding is certainly worthy of further study.

Inconsistent with previous research, the average length of stay in this study hospital was actually longer by 0.75 days in the group of patients that did receive PCI within 90 minutes. Two patients who met the 90-minute benchmark had LOS of 13 and 14 days. Although they were quickly treated with a PCI, they later developed complications requiring surgery, which could have played a role in the non-significant findings of this study. Even though long-term outcomes were not measured, the delay in PCI did not influence the LOS in this study, as might have been expected.

Recommendations and Future Implications

The American College of Cardiology has recently been discussing the additional benefits of reducing the benchmark even further to a 60 minute-or-less time frame. The time would still be a total of 90 minutes but would include a 30-minute allowance for emergency response teams in the field, giving only 60 minutes to the hospitals' portion of the process. In the current study, data showed only 22.5% of the patients would have reached the 60-minute goal, which establishes an even greater need for an increased speed of delivery of care for this facility should the standard change in the near future.

Several of the national suggestions for improvement have already been implemented in this facility. However, throughout the year of this study, two recurring delays were observed that might have influenced the facility's treatment of the patients experiencing AMI. First, there seemed to be a delay or hesitation between reading the ECG and the decision to call in the CCL personnel. Some ED physicians, despite seeing ECG changes indicating AMI, did not activate the paging system for the CCL personnel. Instead, they preferred to allow the cardiologist to read the ECG and determine whether or not to call in the CCL personnel. Second, in the CCL at the start of the case, there was a delay in actual balloon inflation time. When this delay was discussed with the cardiologists and CCL personnel, it became apparent that some cardiologists were performing a diagnostic cardiac catheterization prior to balloon inflation, whereas other cardiologists were proceeding directly to balloon inflation as soon as possible. These are now two areas being further monitored by the ED Clinical Nurse Specialist.

Suggestions for future studies include further detailed analyses of the charts of those patients who did not meet the benchmark, exploring for commonalities. A real-time prospective study in which persons presenting with AMI were actually followed through the system would also be valuable. Factors to consider in future research include time of day, day of the week, staff number and mix available, physician on duty, and CCL availability. It would be crucial to include the testing of different methods used to speed up the process after identifying specifically where a problem lies.

Since the research questions in this study were restricted to one specific hospital, the results can only be generalized to that facil-

ity. One possible limitation is the fact that the study hospital did not have synchronized digital computerized clocks. Although this lack would not affect the determination of whether or not a subject met the 90-minute benchmark, it might result in discrepancies in time due to two departments recording time based on clocks located in separate areas of the facility.

Given the 70% success rate of the study hospital, there is a need to improve patient morbidity and mortality rates resulting from heart disease and acute myocardial infarction, which are among the nation's largest killers. This study highlights the importance of future research into all factors influencing time to reperfusion locally and across the nation.

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Mentor Comments: Ellen Odell emphasizes the independence of Erin Troby's research and its potential importance clinically for one area hospital and for the lives of those served there.

Ms. Troby recently concluded her research at one local hospital; and her project has impact and potential to save lives and improve the quality of medical care with regards to patients experiencing a heart attack. I will not go into detail about the research project itself or the results, but I will tell you that it was extremely successful and a valuable learning experience, not only for Ms. Troby, but also for the staff at the participating hospital agency. Many of the findings from the initial review of literature as well as findings from this study were implemented in the local Emergency Department (ED), and timeframes for treatment have improved over the past one and one-half years. Because of the improvement in patient care and the ability of the agency to meet the benchmark of 90 minutes, the hospital will be applying accreditation as a recognized Chest Pain Center by the Society of Chest Pain Centers. The work involved in the entire project was most definitely Mr. Troby's. She worked independently in most aspects and was totally responsible for getting the work completed. The hospital liaison involved, the Clinical Nurse Specialist (CNS), provided a list of potential subjects and was able to implement several of the findings in the ED. However, as a bonus, the liaison was a graduate of the very first Masters in Nursing CNS class from EMSON in 2007; and this added to the reward of working as a team on such a tremendous project. I have enjoyed working with Ms. Troby during the past year and a half; and although the research process can be tedious and lengthy (especially for students), her excitement for this project never dulled because she understood its importance. This past spring, Ms. Troby successfully completed and defended her research project; and because of her diligence and hard work, she graduated with Honors and Summa Cum Laude recognition. Prior to graduation, she was chosen to be a conference speaker for Sigma Theta Tau International Honor Society of Nursing Pi Theta Chapter at the 19th Annual Nursing Excellence Leadership & Evidence-Based Practice Conference and present her research findings. I am very proud of her and her work. With her solid background of the quality improvement process and her undergraduate experience with research, she will be a tremendous asset to the profession of nursing.

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